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CHAPTER 1 –
Introduction to Configuration Management and Transportation Management Systems

What is Configuration Management?

There are two fundamental purposes of configuration management (CM):

1. Establish system integrity
2. Maintain system integrity

To an individual who designs, develops, operates, or maintains complex transportation management systems (TMSs), the definition of integrity is well understood:

- A system with integrity is one in which all components are well defined and documented.
- A system with integrity is one in which a working baseline is always available to implement and provide transportation management services.
- A system with integrity is one that can be readily integrated with other regional intelligent transportation systems (ITS).
- A system with integrity is one with a high degree of traceability – allowing one to easily identify how system functions are provided technically.

In other words, a system with integrity is one that is available and functional.

Of course, establishing and maintaining system integrity doesn't just happen – it takes real, sustained effort. CM describes a series of processes and procedures developed in the information technology community to establish and maintain system integrity. It is an integral part of the systems engineering process. While some of the terms used in CM may be unfamiliar to transportation professionals, the core concepts and practices of CM are not technically complex. Rather, they represent sound practices in developing and maintaining any system. As you will see in this document, CM makes sense for use in transportation management systems.

Document Purpose

Configuration Management for Transportation Management Systems is intended to provide guidance for transportation professionals who are either (a) seeking to improve change management in a traffic management system or regionally integrated intelligent transportation system by introducing formal CM or (b) using CM currently and require a technical reference to support their activities.

Intended Audience

Configuration Management for Transportation Management Systems is intended to be guidance material for any individual who is engaged with or responsible for the planning, design, implementation, management, operation, or maintenance of transportation management systems. The document includes technically detailed information and examples suitable for individuals directly responsible for a CM program – such as staff engineers, consultants, maintenance personnel, and designers. In addition, the document provides high-level information that is well suited for agency management and policy makers.

The document also is intended to support individuals with varying levels of experience and involvement with CM. First, CM novices can use the document to gain an gain an introductory understanding of the CM. Second, the document is intended to support individuals with a range of experience in CM by providing in-depth information and concrete transportation examples.

FUNDAMENTALS OF CONFIGURATION MANAGEMENT

Introduction to CM

"Configuration Management, applied over the life cycle of a system, provides visibility and control of its performance, functional and physical attributes. Configuration Management verifies that a system performs as intended, and is identified and documented in sufficient detail to support its projected life cycle…The Configuration Management process facilitates orderly management of system information and system changes for such beneficial purposes as to revise capability; improve performance, reliability, or maintainability; extend life; reduce cost; reduce risk and liability; or correct defects. The relatively minimal cost of implementing Configuration Management is returned many fold in cost avoidance. The lack of Configuration Management, or its ineffectual implementation, can be very expensive and sometimes can have such catastrophic consequences as failure of equipment or loss of life."

- EIA Standard 649

CM provides a holistic approach for effectively controlling system change. It helps to verify that changes to subsystems are considered in terms of the entire system, minimizing adverse effects. Changes to the system are proposed, evaluated, and implemented using a standardized, systematic approach that ensures consistency. All proposed changes are evaluated in terms of their anticipated impact on the entire system. CM also verifies that changes are carried out as prescribed and that documentation of items and systems reflects their true configuration. A complete CM program includes provisions for the storing, tracking, and updating of all system information on a component, subsystem, and system basis.

Benefits of CM

There are many reasons that personnel involved with TMSs should be interested in CM. As TMSs are becoming more sophisticated through the addition of new subsystems, integration with other systems, and overall physical expansion, the need to control the rapid pace of change has become apparent.

One problem that has been discovered as these systems change is that groups within an agency often work independently of each other, conducting changes without consulting one another and documenting the changes improperly. If the entire system is to undergo a major change or upgrade, this can present a significant problem. Contractors or agency personnel often will have to devote significant effort to retracing the steps taken for minor changes to the system to understand the current status. Doing so obviously requires major outlays of time and money. CM provides a methodology for identifying, tracking changes to, updating information on, and verifying the status of all items within a system. This provides TMS managers with an up-to-date baseline of their system, which is better understood and better prepared for further change, than a system that does not use CM.

A proper CM program will ensure that documentation (requirements, design, test, and acceptance documentation) for items is accurate and consistent with the actual physical design of the item. In many cases, without CM, the documentation exists but is not consistent with the item itself. For this reason, contractors and agency staff will frequently be forced to develop documentation reflecting the actual status of the item before they can proceed with a change. This "reverse-engineering" process is wasteful in terms of human and other resources and can be minimized or eliminated using CM.

Some of the other benefits of CM, which hopefully will never be needed, are its provisions for disaster recovery. Because a CM program should ensure that an accurate, up-to-date baseline of the system exists, the re-engineering process should be far less costly. Without CM and the associated baselining process, entire subsystems would require redesign at a much higher cost, and the recovery process would be greatly lengthened, if even feasible.

Another benefit of CM is that it provides for administration of change decisions with a system-wide perspective in mind. The configuration control board (CCB) has personnel with various areas of focus and from various departments within an agency. All proposed changes to the system are considered by the CCB in terms of the system, not just particular subsystems. Using tracking tools, unapproved changes can be detected and fixed more easily. As cited by one source for this document, CM also makes it easier to determine contractor error or negligence in making a change because of the tracking capabilities that a robust CM program and CM tool can provide.

In cases of subsystem or system development, CM allows TMS management to track requirements throughout the life cycle through acceptance and operations and maintenance. As changes are inevitably made to the requirements and design, they must be approved and documented, creating an accurate record of the status of the system. The CM process may be (and ideally should be) applied throughout the system life cycle.

Brief Introduction to CM Activities and Concepts

This subsection presents a brief introduction to CM activities and concepts. Please note that chapter 3 of *Configuration Management for Transportation Management Systems* discusses each of the following CM processes in detail.

The general CM process is described graphically in figure 1.1. Following this figure, each element of the process is described, and the benefits of the element are discussed.

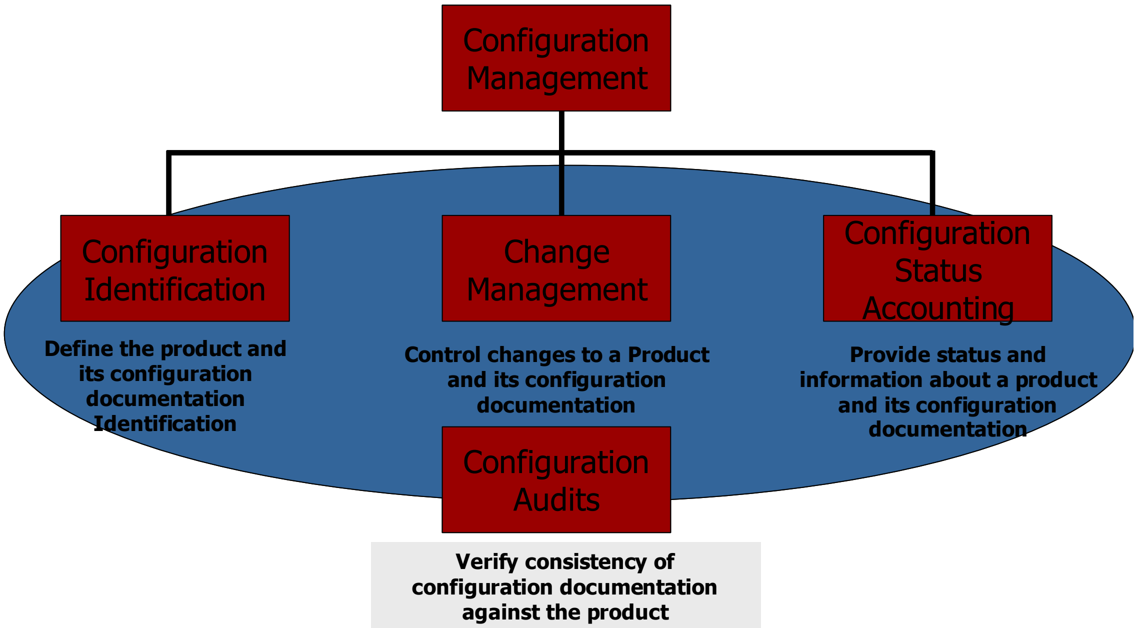


Figure 1.1 – Configuration Management Process

<u>CM Plan</u>

While not shown in figure 1.1, a CM plan is integral to the process. The CM plan is the document that will guide the CM program of a particular group. Typical contents of a plan include items such as:

- Personnel.
- Responsibilities.
- Resources.
- Training requirements.
- Administrative meeting guidelines.
- Definition of procedures.
- Tools/tool use.
- Organization configuration item (CI) activities.
- Baselining.
- Configuration control.
- Configuration status accounting.
- Naming conventions.
- Audits and Reviews.
- Subcontractor or vendor CM requirements.

Plans typically are established at the outset of the CM program and undergo changes as the system evolves and as areas where the plan can be improved are identified. Contractors, in conjunction with the particular agency that will be using the CM program, often develop the plans.

The benefit of the CM plan is that it provides a central location for all CM program information. The items selected for CI depend upon the scope of the effort. For example, CI may be constrained to software items or may be larger and include system level components ranging from software, hardware, firmware, documentation, and perhaps the CM plan. The plan serves as the primary resource for any questions pertaining to the CM program. The primary benefit of the plan is that it clearly outlines how the CM program is to be executed and will leave as little room for ambiguity as possible.

Configuration Identification

Configuration identification is the process of documenting and labeling the items in the system. Depending on the scale of the particular CM program, this simply may involve software versions or, in the case of a large program, all hardware, software, documentation, and the CM plan itself. The goal of configuration identification is to provide a unique identifier for each item to help track the changes to that item and to be able to understand its place in the system. Often, identification involves recording the identifier, maintenance history, relevant documents and other information that will simplify the change process in the future.

The benefits of configuration identification are to provide a means of unique identification of system components to support traceability and change management processes. Proper identification minimizes confusion over various versions of configuration items and facilitates the change control process by allowing items to be more easily tracked as they undergo change.

Change Control

Change control is the process of assessing the impact of a possible change to a system, determining the fate of the proposed change, executing the approved changes, and ensuring that the change is carried through to the proper documentation. Usually, a change is proposed by someone who is working with the particular part of the system that will be changed. Change requests are submitted to the relevant administrative body for review. This body is normally referred to as a change control board (CCB). The CCB will review the proposed change, determine its effect on the overall system and decide whether or not to proceed with it. An important part of change control is ensuring that the change itself is documented and that the relevant configuration item's (CI) documentation now reflects that change.

The primary benefit of an effective change control procedure is that proposed changes are evaluated in terms of their impact on the entire system. Change control allows the changes to be reviewed by personnel with a variety of interests and areas of specialty. This minimizes the negative impacts of changes on other components of the system. Change control also ensures that the changes are properly implemented and within schedule and cost constraints.

Configuration Status Accounting

Configuration status accounting (CSA) is the process of ensuring that all of the relevant information about an item – documentation and change history – is up to date and as detailed as necessary. A primary goal of CSA is to repose CI information necessary to support existing and future change control efforts. A typical CSA system involves establishing and maintaining documentation for the entire life cycle of an object. Status Accounting is ideally carried out in conjunction with change control.

The primary benefit of CSA is that it provides a methodology for updating all relevant documentation to ensure that the most current configuration is reflected in the configuration identification database. CSA accounts for the current status of all proposed and approved changes. The goal of CSA is to provide decision makers with the most up-to-date information possible. Having the most recent information about a CI or changes implemented for a CI helps to reduce research efforts in future change control activities whether implementing a new change or rolling back a change that had a negative or unexpected impact.

Configuration Audits

Configuration verification and audit is the process of analyzing configuration items and their respective documentation to ensure that the documentation reflects the current situation. Essentially, while change control ensures that change *is* being carried out in adherence with the CM plan, configuration audits ensure that the change *was* appropriately carried out. The most important goal of this process is to prevent lost time on future changes due to inaccurate documentation. If discrepancies are located between the documentation and the item, the personnel carrying out the audit will prescribe a course of action for remedying the problem.

The most important benefits of configuration audits are that they verify that changes were carried out as approved by the relevant administrative body and that documentation about an item reflects the current configuration. By ensuring that changes are properly executed and all documentation is updated, configuration audits will facilitate future changes to the system.

RESOURCES

A number of resources that support configuration management programs are available to transportation professionals. This section describes key resources that supplement this report. Furthermore, a comprehensive bibliography on the topic of configuration management is included in appendix B, which allows readers to locate more specific resources.

This document was written to supplement the "general" configuration management standard, EIA 649, from a transportation perspective. This standard is introduced below.

Furthermore, two additional resources stand out as being particularly useful to transportation professionals. First, the Military Handbook, *Configuration Management Guidance* (MIL-HDBK-61), provides an excellent overview of the configuration management process. In addition, *A Guide to Configuration Management for Intelligent Transportation Systems* (FHWA-OP-02-048), published by the Federal Highway Administration, provides a high-level introduction to configuration management from a transportation perspective, and it serves as a sound introductory resource for individuals seeking to learn about configuration management.

Companion Document - EIA Standard 649

As stated earlier, the processes and procedures of CM have been developing in the information technology community for many years. Therefore, this guidance document makes use of a standard developed and refined in this industry – the **Electronic Industries Alliance (EIA) Standard 649 *National Consensus Standard for Configuration Management* (ANSI/EIA-649/-1998)** – which will be referred to from this point forward as EIA 649. EIA 649 is the definitive standard for CM and provides an excellent introduction to the fundamentals of CM. This standard describes all of the important components of a CM program with guidelines and benefits of each. Thus, this guidance document does not attempt to restate or modify EIA 649. Rather, it refers to sections of EIA 649 where appropriate and then relates the material directly to transportation management systems.

Readers seeking detailed technical information are highly recommended to obtain a copy of EIA 649. At the time this document was printed, the standard could be obtained from EIA on line (www.eia.org) for a price of $92. Those seeking general information regarding CM also are advised to obtain a copy of EIA 649; however, it is not absolutely necessary.

A brief description and summary of EIA 649 is presented in appendix A.

HOW TO USE THIS DOCUMENT

It is intended that users of this document will be able either (a) to read it in its entirety as a comprehensive introduction to CM and its application in transportation management systems or (b) to use the document for ongoing support of a CM program by referring to individual sections on a stand-alone basis. Each chapter is structured in the same basic format. First, a general description and discussion of the chapter topic is presented. Next, specific guidance is presented concerning the application of the chapter's topic to transportation management systems. Lastly, detailed examples of the chapter's topic as used in existing transportation management systems are provided.

This guidance document is structured in three key sections, as follows.

Section 1 – General Introduction to CM & Transportation Management Systems

This section provides general information describing CM and presents an overview of the current practices in CM and transportation management systems. As such, this section is well suited as an introduction to those new to this area or management personnel. The following chapters form section 1.

Chapter 1. Introduction

Chapter 2. Configuration Management and Transportation Management Systems – Current Practices

Section 2 – Technical Guidance – CM & Transportation Management Systems

This section provides detailed information on how to implement CM in transportation management systems. It is intended for a technical audience of individuals who are responsible for implementing a CM program. The following chapters form section 2.

Chapter 3. Configuration Management Processes

Chapter 4. Configuration Management Plan

Chapter 5. Configuration Management Baselines

Section 3 – Guidance for Implementing a CM Program

The purpose of this section is to provide guidance to help transportation professionals implement or improve a CM program to support a transportation management system. This section goes beyond the technical details of CM to consider such issues as resources required to sustain a CM program, tools available to support CM, and so forth. This chapter provides material appropriate for both technical personnel and management to consider in framing an agency's program. The following chapters form section 3.

Chapter 6. Configuration Management Program – Making it Work in Your Agency

Chapter 7. Configuration Management and the System Life Cycle

Chapter 8. Configuration Management Tools

Chapter 9. Resources to Support Configuration Management Programs

Finally, the document concludes in chapter 10 with a presentation and discussion of nine guiding principles for CM and transportation management systems.

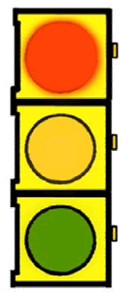
Usage Scenarios

As stated earlier, this document is intended to serve individuals with a variety of backgrounds and goals. Table 1.1 provides guidance for particular “types” of users.

User Type	Recommended Use of Document
CM Novice Technical responsibilities	Section 1 – thorough reading Section 2 – thorough reading Section 3 – focus on chapter 8 & 9 Chapter 10
CM Novice Administrative responsibilities	Section 1 – thorough reading Section 3 – thorough reading Chapter 10
CM Experienced Technical responsibilities	Section 2 – as needed Section 3 – as needed Chapter 10
CM Experienced Administrative responsibilities	Section 1 – especially chapter 2 Section 3 – as needed Chapter 10

Table 1.1 – Document Usage Recommendations

CHAPTER 2 - Configuration Management and Transportation Management Systems – Current Practices



INTRODUCTION

Given the important role of CM in a complex system, it is important to understand how it is currently being used for transportation management systems. A survey was conducted in the spring of 2000 to gauge the use of CM by transportation agencies in the United States. Of the 38 responses the most striking result was that 62 percent of freeway management systems use CM, and only 27 percent of signal systems use CM. These results indicate a need to educate the TMS community about CM in order to realize a significant commitment to this valuable resource-saving activity. The survey also revealed that many of the complex TMSs in this country are not using a formal change control process. As stated in chapter 1, the lack of formal change control processes calls into question the very integrity of many of these systems.

This chapter details the results of the survey. The results are presented in terms of the primary survey sections: TMS characteristics, CM plan, CM process, CM organizational issues, benefits/costs of CM, and testimonials. Please note that this survey was originally conducted for an NCHRP Synthesis project. The full results of this project are published in NCHRP Synthesis 294 (2001).

SURVEY RESULTS

TMS Characteristics

The first section of the survey intended to gauge the size and extent of the responding agency's TMS(s). Such information provided the background needed to identify trends in the use of CM.

The first question of the survey asked about the core functions provided by the TMS. Respondents were to check all that applied, and if a particular agency performed more than one function, then the sample size would increase accordingly. Counting each function independently increased the sample size from 38 to 42. The resulting functional descriptions of the systems were as follows: 20 freeway management systems (FMS), 15 traffic signal control systems (TSCS), 2 automatic toll collection systems (ATCS), and 5 tunnel control systems (TCS). Figure 2.1 illustrates the percentage share of the functional classes of systems.

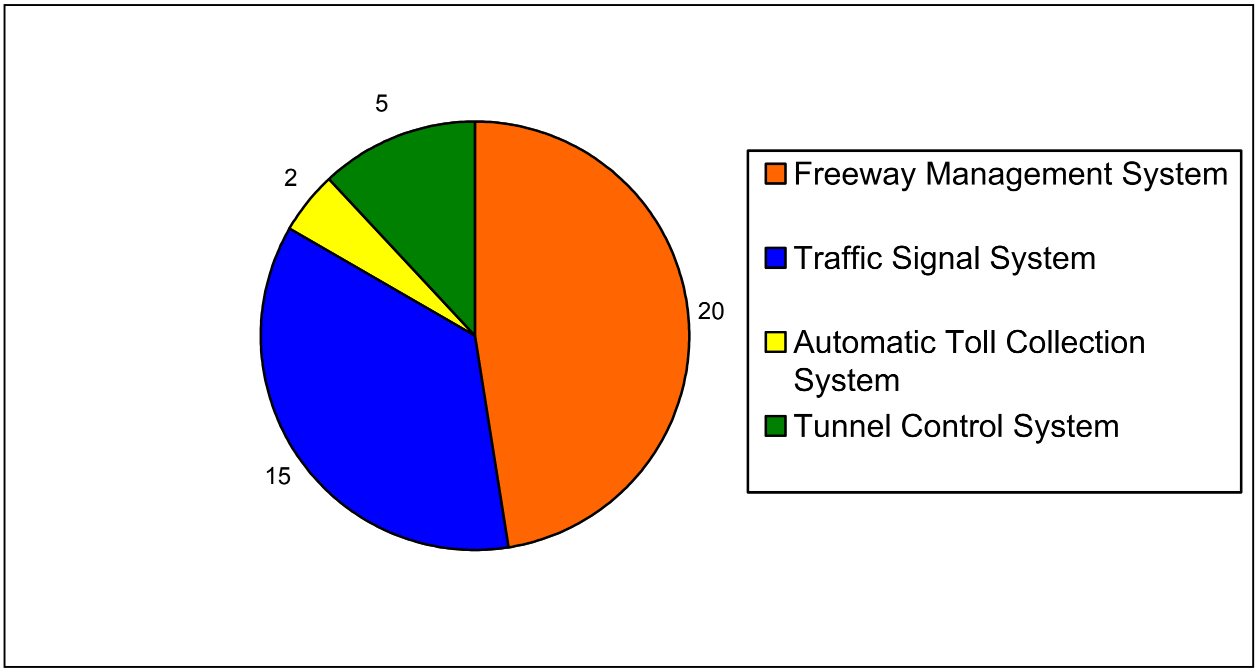


Figure 2.1 Functional Classes of Systems

Respondents also were asked to provide information concerning the size of their system(s). This information was provided in terms of the number of signalized intersections, the lane miles of coverage, the number of CCTV cameras, and the number of variable message signs depending on the functional class of the system. They also were asked about the number and type of detectors, the number of ramp meters, the number of lane control signals, the number of road weather sensors, and the number of toll tag readers. The purpose of these questions was not to collect large quantities of data describing system size, but rather to provide a "check" to ensure the responses regarding CM were not skewed towards one particular size or type of system. A review of the responses indicated that the survey achieved a representative sample of the range of system classes and sizes throughout the country.

A key finding of the survey was that a relatively low percentage of TMSs use CM. What was particularly notable is that only 27 percent of signal control systems reported using CM. Table 2.1 illustrates the use of CM according to the function of the TMS. For the purposes of this table, automatic toll collection systems and tunnel control systems were grouped with freeway management systems.

	Traffic Signal Control Systems	Freeway Management Systems
Percentage of Systems Using CM	27%	62%

Table 2.1 Use of CM by System Classification

Another clear trend in the survey responses is that the likelihood of a TMS using CM is dependent on the size of the system. Larger systems are more likely to utilize CM, as seen in figure 2.2.

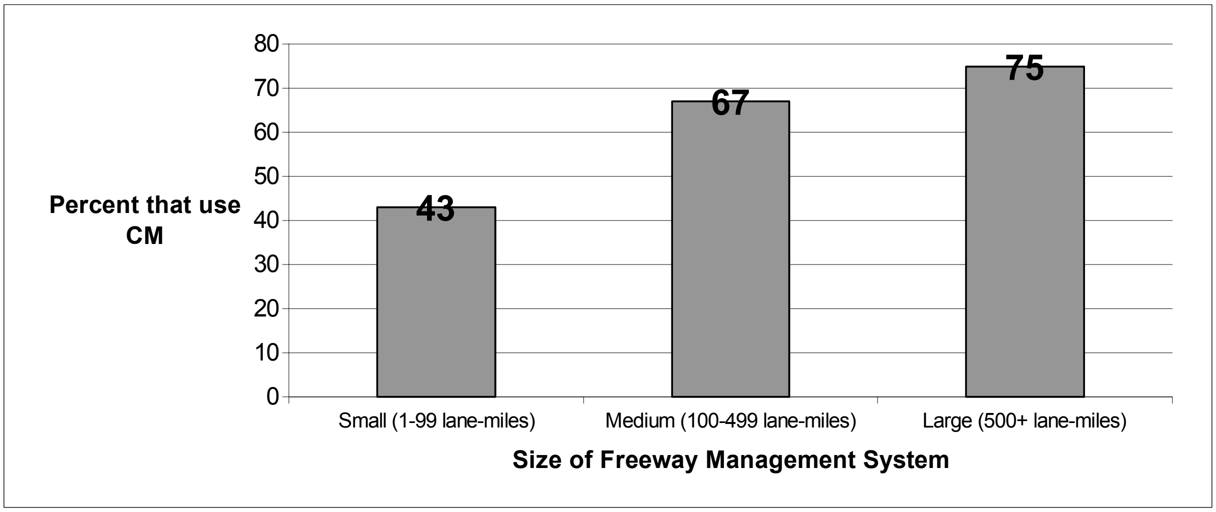


Figure 2.2 CM Use by System Size

Transportation agencies have used different types of core system software in TMSs. The software can be classified as custom developed software, for which the agency either does or does not own the source code, or the software can be classified as off-the-shelf and is typically purchased from a vendor. Fourteen of the departments use custom software for which the agency owns the source code, and ten of the departments use custom software for which the agency does not own the source code. Eleven of the agencies use an off-the-shelf software package purchased from a vendor. Figure 2.3 illustrates the distribution of software types.

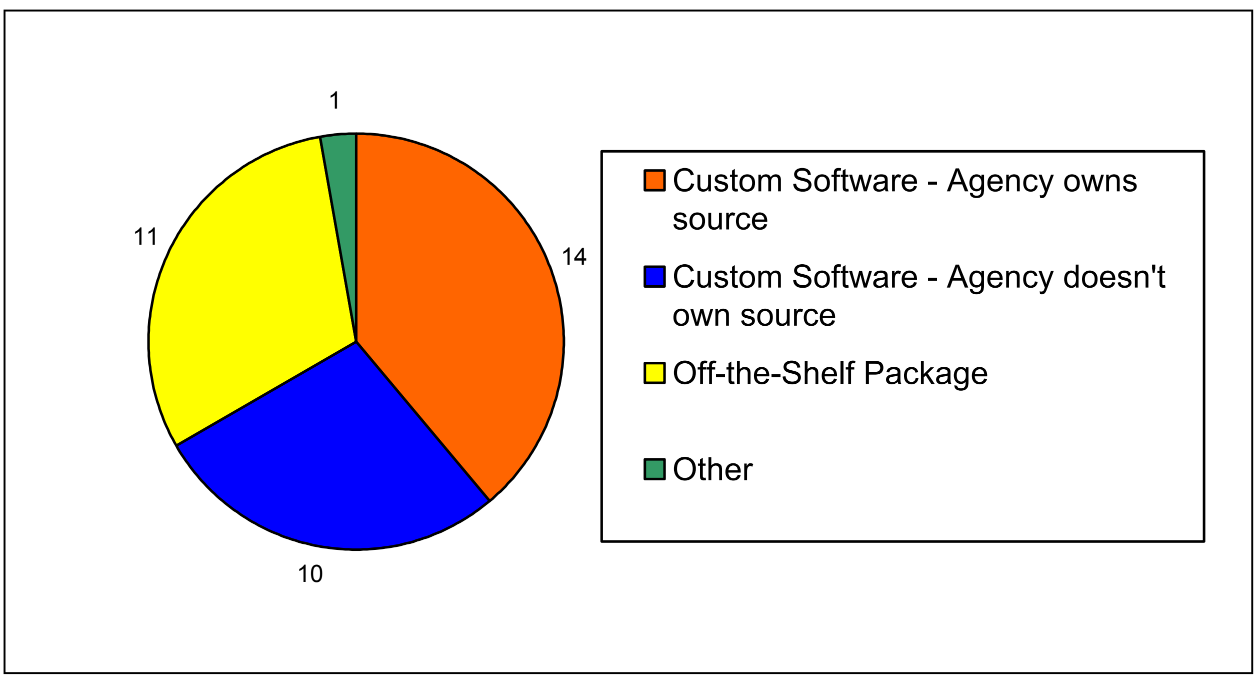


Figure 2.3 Core System Software

Most of the core TMS software was purchased in the 1990s. To quantify the size of the software systems, the average size of the survey responses is 264,000 lines of code and 94 megabytes of executable code. Finally, it is interesting to note in figure 2.4 that agencies are much more likely to use CM if their system uses custom software. This likely reflects the fact that changes to a custom system are more likely (and feasible) in a custom system built specifically for the agency's requirements. Furthermore, this also reflects the wider use of CM in freeway management systems. Of the 11 off-the-shelf systems identified in figure 2.3, 8 are signal control systems, which is consistent with the finding that only 27 percent of signal control systems use CM.

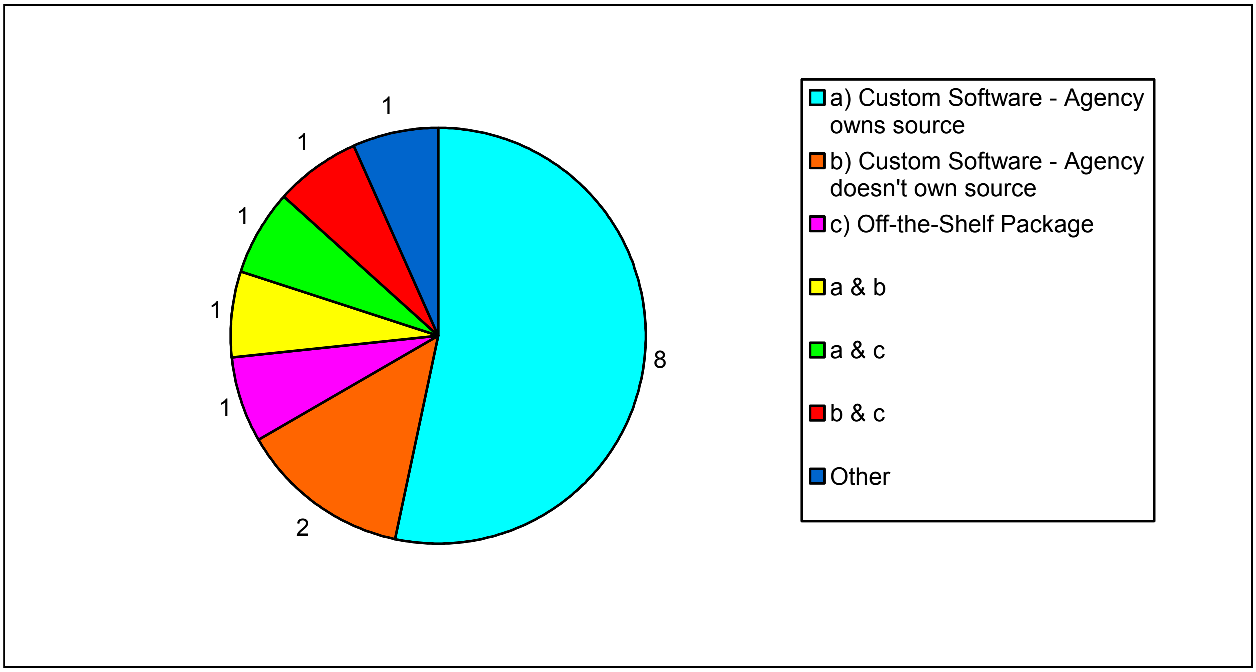


Figure 2.4 Use of CM Based on Software Class

CM Plan

Given the size and cost of the TMSs being operated in this country, many transportation agencies have realized the need to institute formal CM to control changes in the systems. However, many transportation agencies have not become aware of this need until after the development phase of a system, when system operation and maintenance begins. This is particularly evident in the general lack of formal CM plans in TMSs. As seen in figure 2.5, of the 15 agencies that use CM, only 4 have a formal CM plan.

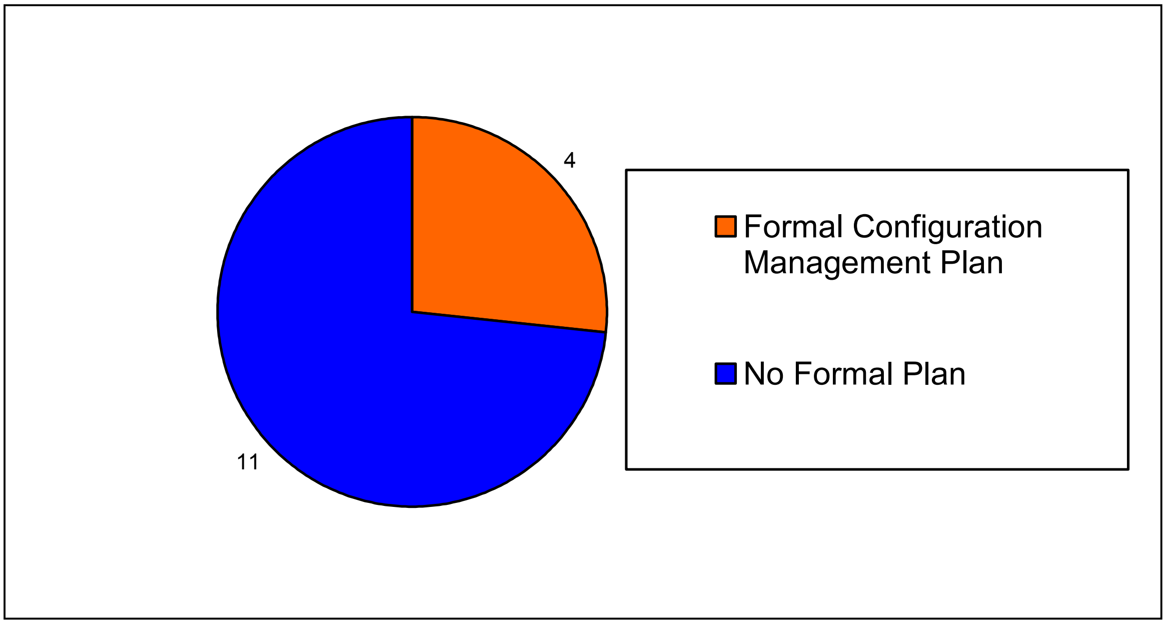


Figure 2.5 Percent of Agencies Using CM that Have a Formal CM Plan

The four agencies that do possess a formal plan report that the plan is very important in ensuring an effective CM process. On a scale of 0 to 10 (10 being highly effective and 0 being completely ineffective), the importance of the plan on the effectiveness of the CM process received an average rating of 7.25. Yet not one of these agencies required system contractors to deliver a CM plan in its request for proposals for the initial system, which reveals a potential disconnect between the development and operations/maintenance phases of TMSs.

CM plans can address several different areas, including, but not limited to CM organization, CM responsibilities, CM training, configuration identification, change control, configuration status accounting, and configuration auditing. The regions and their plans' respective elements are illustrated in table 2.2. Note that all plans address organization and configuration control, but only half of the plans address training, accounting, or auditing.

Table 2.2 Elements of CM Plans

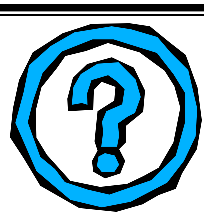
Region	CM Organization	CM Responsibilities	CM Training	Configuration Identification	Change Control	Status Accounting	Configuration Auditing
Miami	X	X		X	X		
Los Angeles	X	X	X	X	X	X	X
Charlotte	X		X	X	X	X	
Georgia	X	X			X		X

The agencies used many resources in the development of their respective CM plans. These resources included, but were not limited to: IEEE Standards, Software Engineering Institute, DOD Standards, and sample CM plans. Table 2.3 shows the resources used by each region.

Table 2.3 CM Plan Resources

Region	IEEE Standards	Software Engineering Institute	DOD Standards	Sample CM Plans
Miami		X	X	
Los Angeles	X			X
Charlotte				
Georgia	X	X		X

Both agency staff and consultants contributed to the creation of the CM plans. To provide some context in terms of the resources required to develop the plans, Miami reported spending 800 hours on its plan, while Georgia Department of Transportation (GDOT) spent over twice that amount of time. (The Georgia system, however, covers not only the City of Atlanta, but also 5 surrounding counties and the Metropolitan Atlanta Rapid Transit Authority (MARTA) for a coverage of more than 220 freeway miles). In terms of funds, Los Angeles invested $80,000 in its plan, while Georgia invested $193,000.



For more information on configuration management planning, see chapter 4.

CM Process

The next section of the survey dealt with issues related to the CM process used by the transportation agencies. One of the first issues addressed was the type of tools used by agencies to support their CM processes. Figure 2.6 illustrates the tools used by transportation agencies and their relative frequency of use. It should be noted that the three respondents who reported Excel as their CM tool have used this spreadsheet package as a simple means to document configuration items. It does not provide the full functionality that the other tools include.

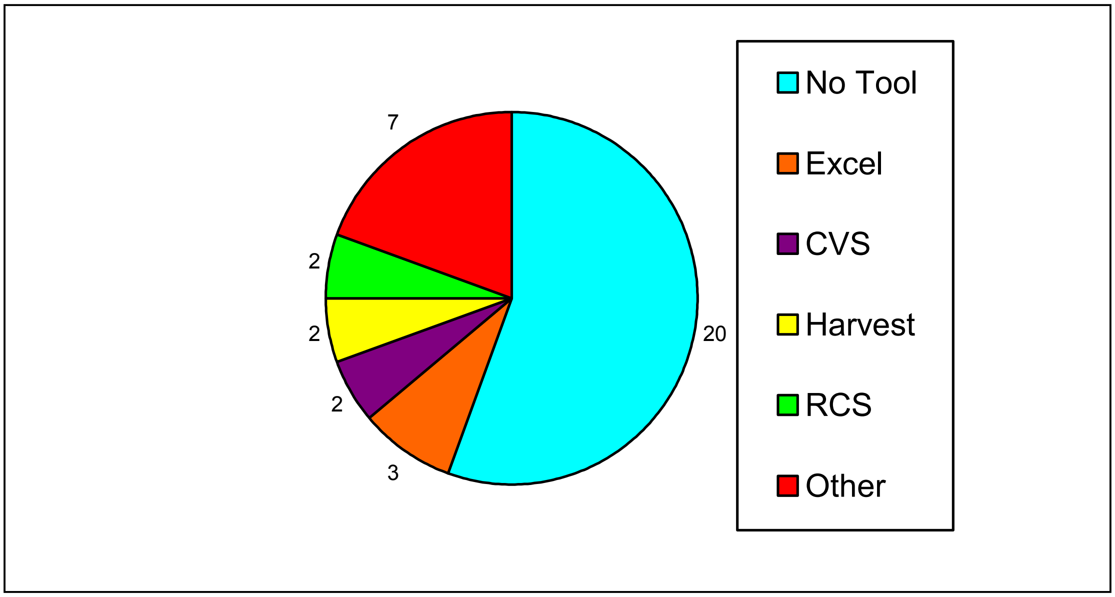


Figure 2.6 CM Tools Used by Agencies

For more information on configuration management tools, see chapter 8.

The survey results reveal that at different stages of the TMSs life cycle, different organizations (the transportation agency, the agency's consultant, or the agency's contractor) led the CM process, as seen in figures 2.7, 2.8, 2.9, and 2.10. While the transportation agency is most likely to lead the CM process during the planning, operations, and maintenance phases, a consultant is usually responsible for CM during the design and development phases. Furthermore, some agencies preferred to use the system's contractor during the design and development phases. These facts illustrate a key challenge in TMS CM – coordinating multiple parties' involvement in CM throughout the life of the system.

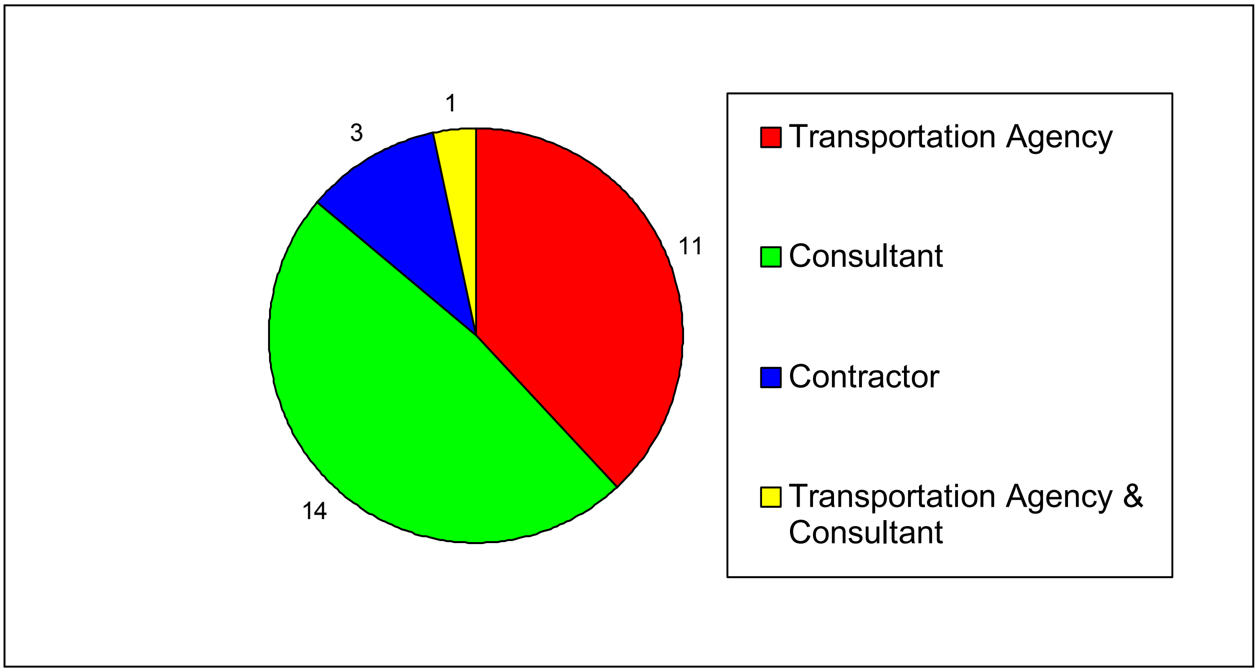


Figure 2.7 Lead Organization During Planning Phase

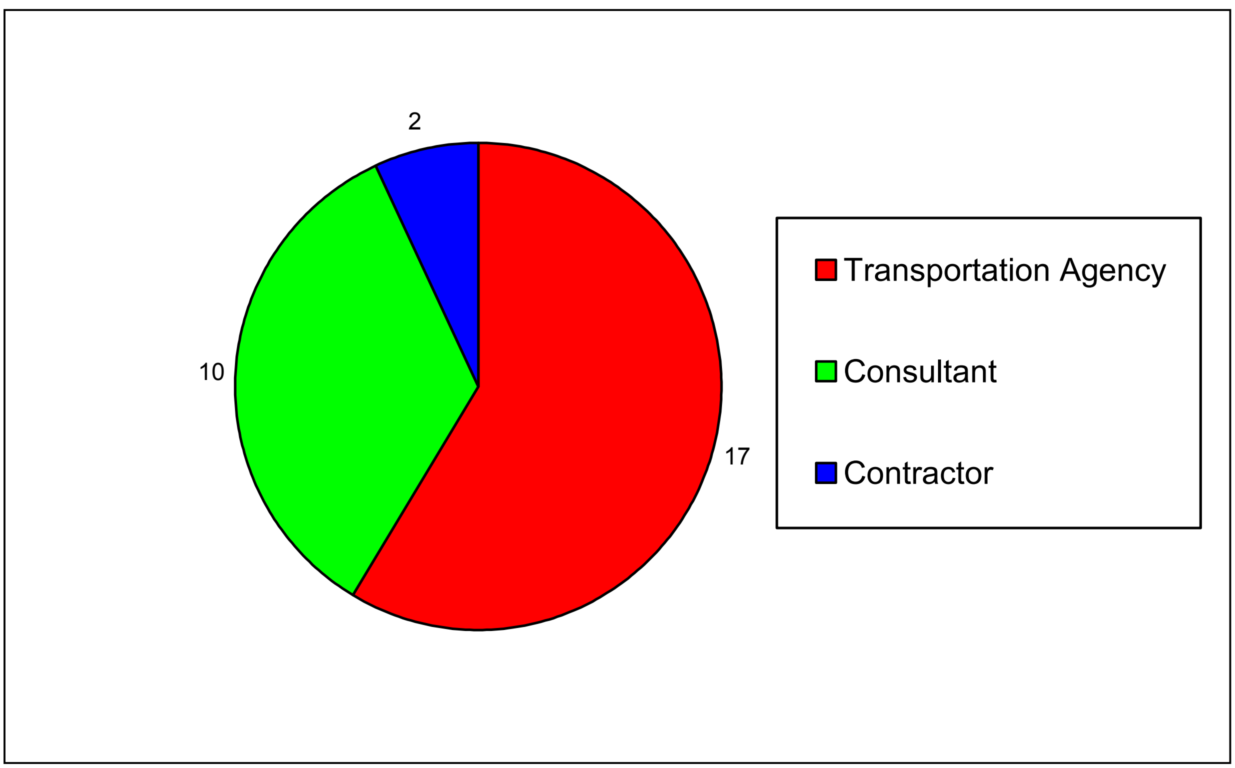


Figure 2.8 Lead Organization During Design Phase

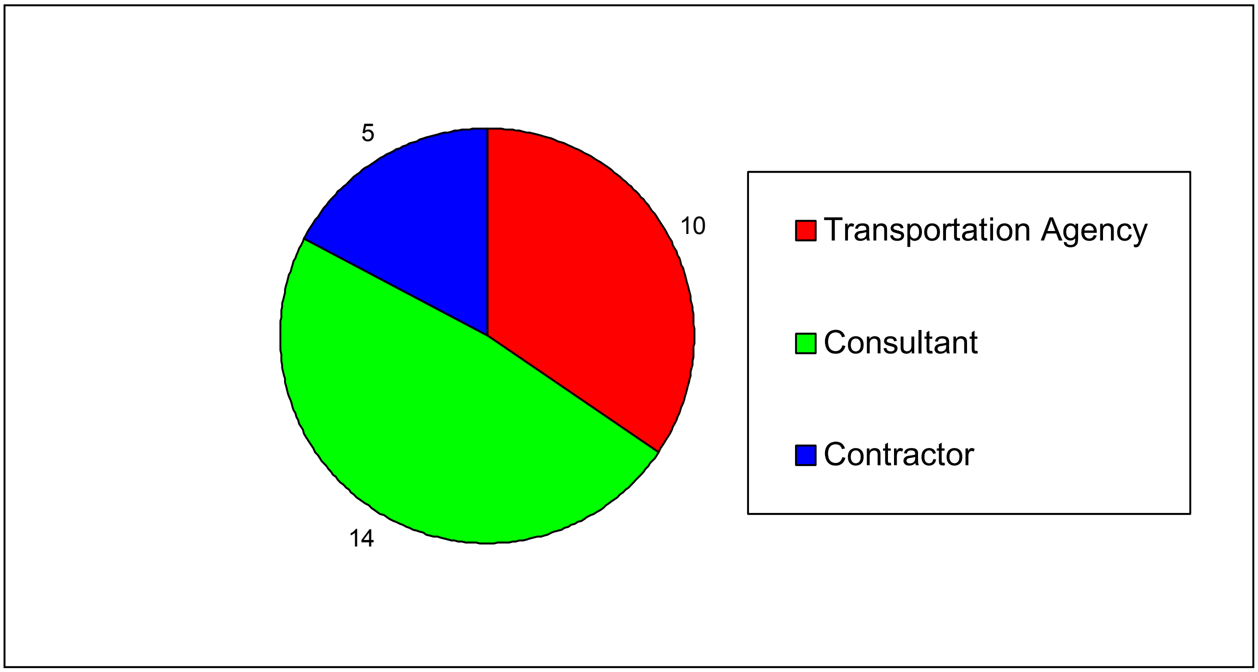


Figure 2.9 Lead Organization During Development Phase

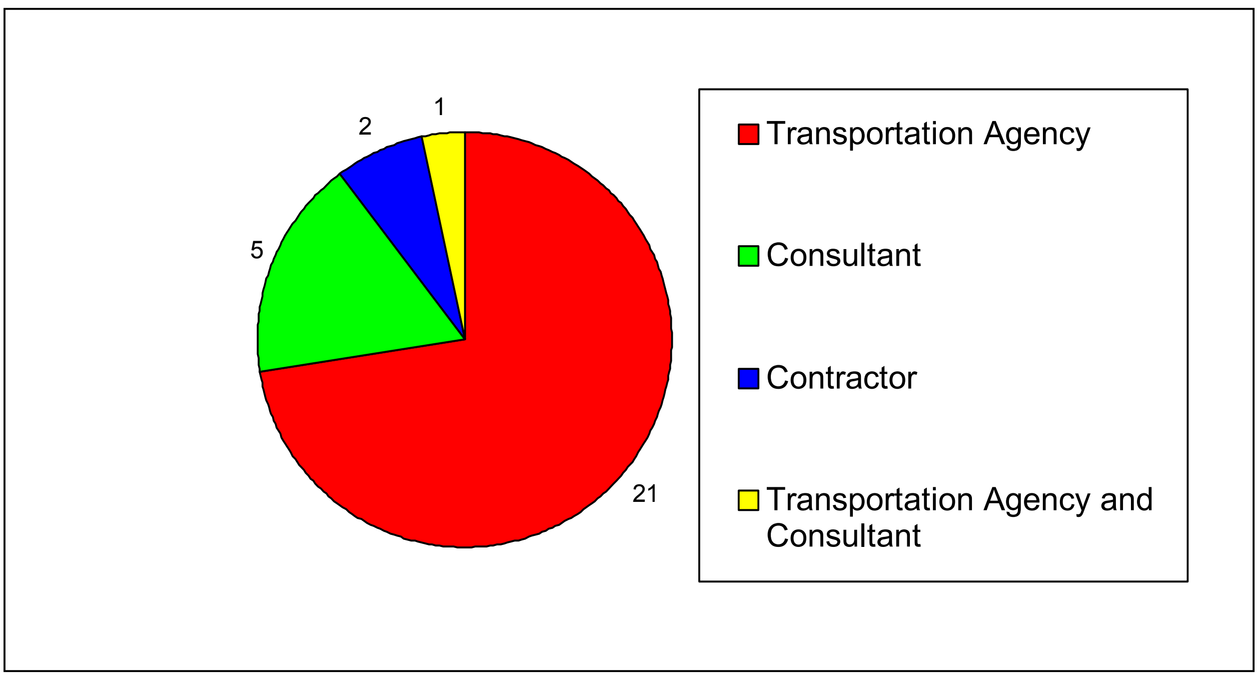


Figure 2.10 Lead Organization During Operations & Maintenance Phase

For more information on configuration management and the system life cycle, see chapter 7.

Traditionally, CM is linked to managing change in software development. Hence, the largest number of transportation agencies used CM with the software elements of their TMSs. As seen in figure 2.11, however, many of the agencies also used CM to manage change in the following subsections of their TMSs: computer hardware, field equipment, databases, and communication systems.

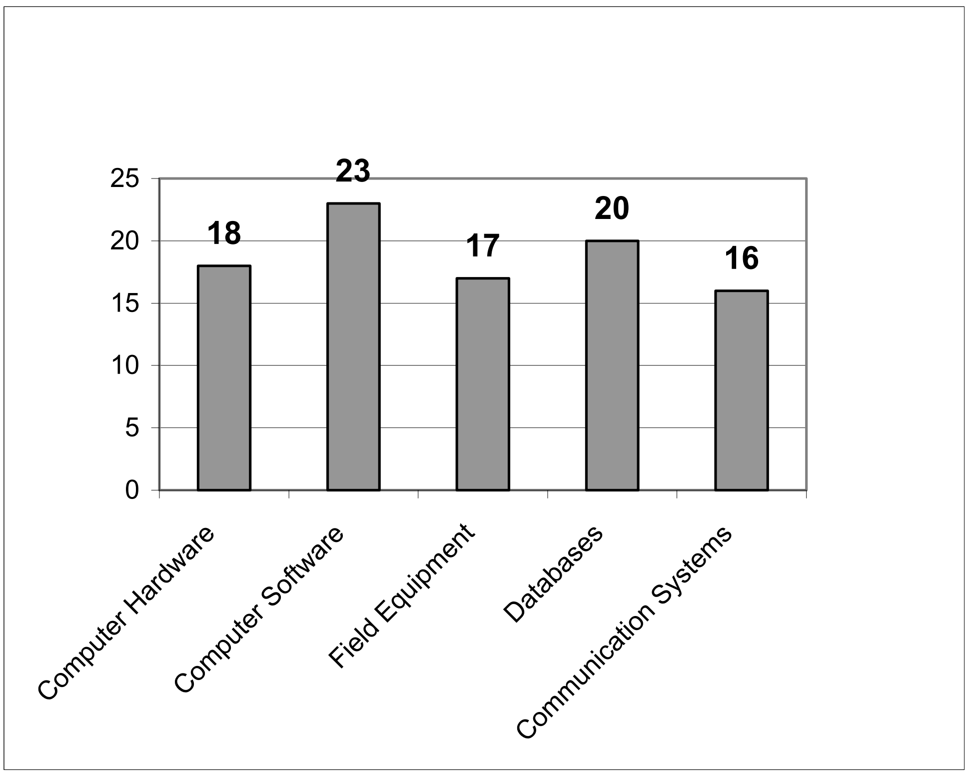


Figure 2.11 Subsystems Covered by CM

The CM process generally consists of the following basic activities: configuration identification, change control, and status accounting and auditing. Some departments surveyed included all of these activities, while others included just a few. Figure 2.12 illustrates which activities were most frequently included in CM processes. Note that the totals in this figure are out of the 19 respondents that indicated they use some sort of formal CM process.

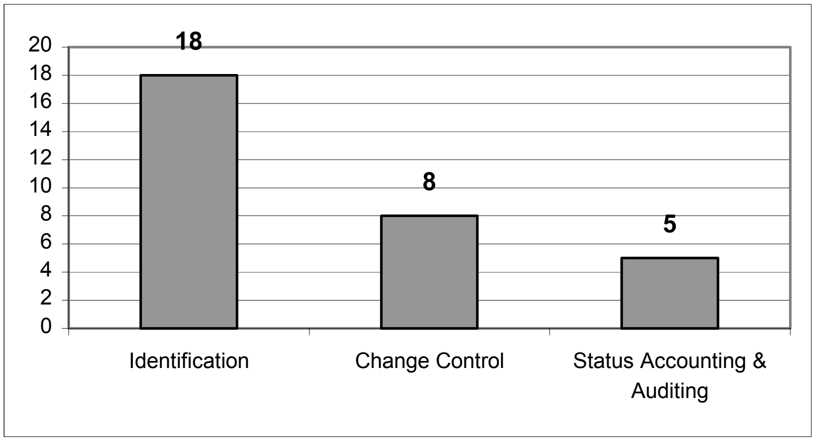


Figure 2.12 Agencies Including CM Elements

For more information on configuration management processes, see chapter 3.

CM Organizational Issues

As seen in figures 2.7 – 2.10, transportation agencies are centrally involved in CM through all phases of TMSs' life cycles. Even during the phases in which agencies generally choose to utilize a consultant or contractor for CM support, the agency remains ultimately responsible for changes in the system. This section of the survey addressed two key organizational issues, the use of change control boards and training.

Eight of the agencies surveyed used formal change control boards to oversee CM activities. The boards ranged from 1 to 16 people, with an average of 5 people. Most boards met a couple of times a month and also during any emergency situations.

A surprising finding from the survey is that only 7 out of 29 (24 percent) of the individuals responsible for CM had actually received formal training in the area. Those that did receive training most often obtained it in a short-course format. This finding points to the need to provide better CM training opportunities to support the transportation engineering community.

Detailed information about change control boards may be found in the change control section of chapter 3.

Benefits/Costs of CM

Most of the agencies responding to the survey reported that the benefits gained from CM were well worth the costs required. Table 2.4 presents the average survey rating for a series of CM benefits. The ratings were on a scale of 0 to 10, with 0 representing no benefit and 10 representing the highest level of benefit. Note that according to the survey responses, the largest benefits of CM are seen in the ability to maintain systems and in improved system reliability.

System Reliability	System Maintainability	Ability to Upgrade System	Ability to Expand System	Ability to Share Information with Other Systems	Ability to Integrate with Other Systems
7.8	8.3	7.5	7.4	5.8	5.7

Table 2.4 Average Benefits Ratings for CM (Scale: 0 – 10)

Survey respondents also rated various CM costs on a scale of 0 to 10, with 10 being the highest cost and 0 being no cost at all. An important result in this section of the survey is that none of the cost categories received an average score greater than 4.1 out of 10, which indicates that most of the agencies using CM find the costs associated with it to be reasonable. The areas that require the greatest levels of resources are agency personnel time requirements and consultant contract costs. The complete results are displayed in Table 2.5.

Agency Personnel Time Requirements	Consultant Contract Costs	CM Tool License Fee	Training Costs	Lost Productivity due to CM Overhead
3.9	4.1	1.9	2.8	2.4

Table 2.5 Average Cost Ratings for CM (Scale 0 – 10)

Finally, when asked to rate if the overall benefits of CM were well worth the costs, on a scale of 0 to 10 (with 10 being complete agreement, and 0 being complete disagreement), 77 percent of the agencies gave a rating of 7 or higher. Again, this strongly indicates that of the relatively small percentage of agencies using CM, the experience has been positive.

CM Benefit Testimonials

Some of the most important information gathered from the survey process can be found in the testimonials of agency personnel on their experiences with CM. Most of the individuals were strong supporters of CM as evident in the following statements.

> *With almost 20 years experience in the design, implementation, modification and expansion of our system, the benefits of quickly being able to recover from problems by returning to an earlier working state are enormous. Our system has been very dynamic, and there is always*

some area where we are working on an improvement or upgrade, while still actively managing traffic.

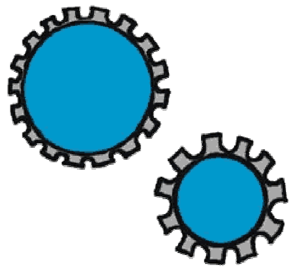
As in any large, complex system, CM can provide a constant understanding of the current state of the system…. The key factor in CM is having a central repository of information for reference as personnel changes occur over the life of the system. It also is a great aid in maintaining the system when items are replaced for repair. Technicians should have ready access to configuration data when installing or re-installing standard system components.

A formal, documented configuration control process can save operational costs over the life of the contract and mitigate the impact of personnel and equipment changes.

Finally, a number of excellent insights into the challenges of instituting CM in a TMSs organization were offered by the Georgia Department of Transportation:

- *User acceptance is slow - people have to become convinced of the importance of CM over time.*
- *Development and implementation of CM requires a significant investment in both human resources and capital.*
- *CM must be implemented as early as practical in the development of the system and continued throughout the system's life cycle.*
- *There is a delicate balance between the time spent on CM and the rewards to be gained.*

CHAPTER 3 -
Configuration Management Processes



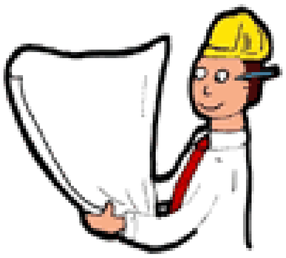
INTRODUCTION

This chapter provides detailed information on how to "do" configuration management. It covers the major components of the formal CM process including:

- CM planning.
- Configuration identification.
- Change control.
- Configuration status accounting.
- Configuration audits.

In each section, EIA 649 is used to explain the particular CM process. This is followed by implementation guidance designed to help transportation professionals apply EIA 649 principles to TMSs. Finally, examples of effective current CM transportation practices are described.

CONFIGURATION MANAGEMENT PLANNING



One of the most important processes involved in the CM program is CM planning. Because the plan serves as the foundation for all other CM activities, it is essential that the plan receive significant thought and effort.

The CM plan typically addresses all items concerning the CM program, including:

- Personnel.
- Administrative bodies.
- Activities.
- Items under CM.
- Policies.
- CM tool descriptions.

Because of the critical importance of CM planning, an entire chapter (chapter 4) in this guidance document has been devoted to the topic.

For more information on configuration management planning, see chapter 4.

CONFIGURATION IDENTIFICATION

Configuration identification refers to the activities and processes dedicated to creating and maintaining full documentation describing configuration items. A CI may be defined as anything that has a function in the TMS. Therefore, system components classified in the broad categories of software, cabling, and hardware are considered as configuration items, in addition to system requirement and design documentation. Configuration identification includes processes such as item naming, drawing and document management, information management and baselining. Configuration identification is the first and possibly most time-consuming process in CM, and if done correctly, will result in significant long-term benefits.

EIA STANDARD 649 DEFINITION

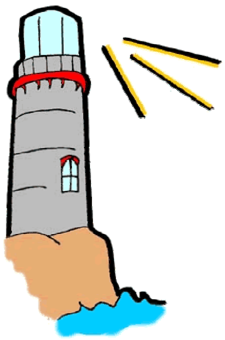
"Configuration identification is the basis from which the configuration of [items] are defined and verified; [items] and documents are labeled; changes are managed; and accountability is maintained"

As stated in EIA 649, the purpose of configuration identification is to document each item in such a way that its operation, functionality, capabilities, and configuration are fully described. Also, specific to hardware, it is important to document location, maintenance, and warranty information.

After determining what information about each item needs to be documented, the next step of configuration identification is to determine the overall structure of the documentation system. EIA 649 recommends that the CM manager begin documentation at high levels of functionality, which is usually a system of items, then document each item in that system, and continue until the lowest levels of functionality are documented. A simple example of this is to consider a variable message sign system. The system has a high level of functionality. After its information is documented, then the signs, software, and other hardware that are integral to the system should be documented as well.

Another step of configuration identification is configuration item identification, which defines how the items should be named. Obviously, the naming system should be consistent, and it should allow users of the system simple access to the documentation about each item. Some DOTs have come up with a system for naming that is independent of many standards. Georgia DOT, for example, has a system in which all items have the same prefix, followed by a number that identifies the item as a document, software, hardware, and so forth, which is then followed by a unique number from 1-999. The system's simple nomenclature serves the state's needs according to the CM manager.

IMPLEMENTATION GUIDANCE



There are many important points to consider when developing a system for configuration identification. Successfully implementing such a system is essential to serve as a foundation to support system maintenance and change control. System managers may want to develop their own identification systems based on the needs of their personnel and the complexities of the involved systems. One of the professionals who was interviewed during the development of this report stated that there is no such thing as too much information for a configuration item. All of the information may be useful at some point during the system's life cycle, but limited memory or limited time available for data entry may place restrictions on this approach. It therefore becomes necessary for the CM manager to determine what information is critical for an agency's daily operation.

Level of Configuration Identification – Software

Software configuration management can best be considered in two broad categories: custom and commercial-off-the-shelf (COTS). Custom software refers to applications developed specifically for a TMS. In this case, generally the TMS receives both source code and executable code corresponding to the application. Source code is the English "readable" code statements, written by programmers and stored in individual files. This is the original composition of software before compilation into object code, also known as executable code, which drives or runs a particular application in a computer system. The executable code is the complete program, which is intended to run on an agency's computer. COTS software, on the other hand, is generally only provided to an agency in executable form. In this case, the software is used by many organizations, and the TMS simply maintains a license allowing their use.

For both custom and COTS software, the information items to include in configuration identification are similar. These items include:

- Item's unique identifier.
- Storage location.
- Required hardware and operating system.
- Associated directories and libraries.
- Version number.
- Updates.

The level of detail, however, is different between COTS and custom software. For COTS software transportation agencies usually record the above information for an entire functional application, because the agency generally cannot change one portion of the application. Changes are restricted generally to updates and new versions of the COTS software. For custom software an agency establish and document configuration items down to the level of software modules because custom software allows the user to modify a single module within the application.

Level of Configuration Identification – Hardware

When establishing and maintaining configuration identification for hardware elements of a TMS, it is important to consider at what level the hardware items will be controlled. Suggested levels for hardware documentation are listed and described in figure 3.1. A DOT's identification requirements may vary depending on such things as its ability to maintain items, expected growth, and functionality. As stated in *A Guide to Configuration Management for Intelligent Transportation Systems*, the *parts, subassembly, assembly*, and *unit* levels of configuration control are the only ones appropriate to managing an ITS system. If an agency plans on recording the model number of an item, it would be controlling at the *assembly* level. At this level when the item fails, it is replaced. At the *subassembly* and *parts* levels, the item is tested to see what part of it failed, and then that part or parts is fixed. At the *unit* level an entire functional group is treated as the same item. Although this would require a lot less information to be stored, replacing an entire traffic signal cabinet when one item fails is clearly unreasonable. The majority of states surveyed control their configuration at the *assembly* level, since most of their system components are purchased from third parties. It is therefore suggested that agencies use the *assembly* level to achieve hardware configuration identification.

Levels of Control

- Part – one piece (or two or more joined together pieces) not normally subject to disassembly without destroying or impairing the part's designated use. Example: a processor chip.
- Subassembly – two or more parts that form a portion of an assembly or a unit replaceable as a whole, but having a part or parts that are individually replaceable. Example: a printed circuit board.
- Assembly – a number of parts or subassemblies (or any combination thereof) joined together to perform a specific function. Example: a traffic signal controller.
- Unit – an assembly or any combination of parts, subassemblies, and assemblies mounted together, normally capable of independent operation in a variety of situations. Example: a traffic signal controller cabinet.
- Group – a collection of units, assemblies, or subassemblies that is a subdivision of a set or system, but is not capable of performing a complete operational function. Example: time-based coordinated system.
- Set – a unit or units and necessary assemblies, subassemblies, and parts connected or associated together to perform an operational function. Example: closed-loop system.
- Subsystem – a combination of sets, groups, and so on that perform an operational function within, and are a major division of, a system. Example: regional automated traffic control subsystem.
- System – a combination of parts, assemblies, and so on, joined together to perform an operational function or functions. Example: an automated traffic system.

Figure 3.1 Levels of Hardware Configuration Identification

* *Mitretek.* A Guide to Configuration Management for Intelligent Transportation Systems*. April 2002 (p. 5)*

Tool Use

The complexities of keeping detailed records for all of the CIs raise the issue of tool use for configuration identification. Many transportation agencies utilize software tools that are designed specifically for CM to manage their CIs. For identification purposes, these programs usually include large databases in which the information about the configuration items may be stored and modified. Other organizations, with less complex CM programs, use relatively simple spreadsheets to keep track of their CIs. As system complexity increases and the number of CIs increases, the need for a robust CM tool emerges.

For more information on configuration management tools, see chapter 8.

Baselining

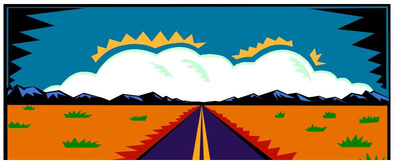
A baseline consists of all documentation on items that are under change control, the items themselves, and all approved changes that are being made to the system. The importance of establishing baselines cannot be emphasized enough when discussing configuration identification. Because of the frequent changes that occur to a TMS, it is important that hardware, software, and documentation are regularly baselined, using a standardized procedure to identify all of the changes that have taken place.

According to agencies that provided information for this report, baselining saves tremendous amounts of time because it tends to minimize redundancy and the need to retrace steps. Baselining is essential in software development environments. Many agencies have systems that allow software developers to “check out” versions of the object code for enhancements. Instead of being checked back in with the same identification, it receives new identification and is considered the new baseline for this piece of software. A CM manager or committee should approve the new version before it receives its unique identifier and becomes the new baseline.

Chapter 5 is dedicated to the topic of baselining.

Consistency

In order to ensure effective configuration identification, consistency should be a primary concern. Specific persons or committees should be responsible for determining CIs and the information that is to be recorded. Proceeding in this manner means that standardized formats are used for identification and the end users has a consistent format with which to work. Having a person or persons in charge of configuration identification activities who consistently collects accurate information helps to provide the traceability of the decision-making process to the actual configuration. This allows the organization to know the rationale behind decisions so that one person or group does not make changes that conflict with another.



Implementation Guidance Summary

A CM manager should determine the agency's level of configuration identification *(part, subassembly, assembly, unit, group, set, subsystem, system)* based on the complexity of its system and the anticipated frequency of change.

A tool, which can be anything from an extensive database to a spreadsheet, is the best way to keep track of configuration item information.

For software, a tool that allows code to be checked in and out is essential to maintaining system integrity.

Having a centralized authority, which determines configuration items and the necessary information to collect on each leads to a more standardized and accountable system.

BEST TRANSPORTATION PRACTICES

This section presents a number of examples of configuration identification practices employed by transportation agencies.

Configuration Item Determination

CI determination is the first step of CM after the development of the plan. It is how a transportation agency determines what is going to be included in its change control and what is going to be left out of its baselining procedures. The first step that CM managers use in CI determination is the statement of purpose of the CM program from the DOT or agency that created the system.

Maryland CHART II System

The Maryland Coordinated Highways Action Response Team (CHART) II plan states, "the goal in selecting CIs is to provide meaningful management visibility and tracking." The plan also details the need for determining the overall structure of the system in order to determine the correct level of configuration identification. The plan states, "defining configuration identification at too low a level results in over-control of system development and overly complex and costly CM. On the other hand, identifying CIs at too high a level reduces management visibility into the project and can make progress difficult to control, manage, and verify."

After giving a general description of how to determine a CI, the plan goes on to detail the five major categories of CIs. Since the CM system only covers the software used in the CHART system, all items are categories of software, documentation, or related hardware (workstations, servers, etc.), but not hardware that is deployed in the field.

Richmond, VA Smart Traffic Center

The Richmond Smart Traffic Center (STC) CM plan takes a more comprehensive approach than does the Maryland CHART II plan. Instead of giving a guideline and then a general outline of the items that should be included under change control, the Richmond STC plan includes an appendix that "identifies the baseline software, firmware, documentation, and hardware that will be the responsibility of the CCB". Included as an appendix, this section lists all the CIs by name. Although the CCB has the authority to add new CIs to the list, it appears to be exhaustive and attempts to list all the items to be placed under baseline control. The following list is from an appendix included in the Richmond plan, which details all documentation under change control:

Documents Subject to Configuration Management Controls

- System Requirements Specification, v1.7
- Acceptance Test Plan, v1.0
- Software Development Plan, v1.0
- System Test Plan, v1.0
- Database Design Document, Final-2
- Build Document, Final-1
- Computer Operator's Manual, Draft-3
- Software Design Description of the CCTV, Final-1
- Software Design Description of the Dialup Communications Component , Final-1
- Software Design Description of the Event Logger Component, Final-1
- Software Design Description of the Graphical User Interface Component, Final-1
- Software Design Description of the HAR, Final-1
- Software Design Description of the Incident Detection, Final-1
- Software Design Description of the Incident Management, Final-1
- Software Design Description of the Scheduler Component, Final-1
- Software Design Description of the Security Service Component, Final-1
- Software Design Description of the Serial Communications Component, Final-1
- Software Design Description of the Socket Communications Component, Final-1
- Software Design Description of the Transportation Sensor Station, Final-1
- Software Design Description of the VMS Component, Final-1
- Software Design Description of the VOIS Sender Component, Final-1
- Software Design Description of the Web Mapper Component, Final-1
- Software Design Description of the Work Zone Component, Final-1
- System Test Description for CCTV, Draft 5
- System Test Description for Condition Monitoring, Draft 5
- System Test Description for Equipment Management, Draft 2
- System Test Description for HAR, Draft 4
- System Test Description for Incident Detection, Draft 4
- System Test Description for Incident Management, Draft 4
- System Test Description for Other, Draft 2
- System Test Description for ITS Scheduler, Draft 4
- System Test Description for VMS, Draft 5
- System Test Description for Work Zone, Draft 4

<u>Southern California Priority Corridor</u>

The Southern California Priority Corridor (SCPC) CM initiative also has a policy regarding configuration identification. The plan states that CIs are “aggregations of deliverable documents, software products, and hardware.” The plan also includes selection criteria that state that potential CIs should be evaluated on the basis of their impact on other projects, number of potential deployments, and impact on system consistency. Similar to the Maryland CHART II plan, a list of general categories that should be included in CM is included, although individual items are not named. The following is an excerpt of the CM plan, which lists the types of items that are to be maintained under configuration control:

- Developed software, firmware, and hardware
- Supporting COTS software, firmware, and hardware
- Project documents such as: Concepts of Operations, User and System Requirements, High Level and Detailed Designs, etc.
- Development systems such as: development environments, tools, COTS software, build notes and procedures, and all other information needed to fully develop the configuration item.
- Test systems such as: test environments, test plans, test software, procedures, simulators, tools, test equipment, COTS software, and notes used to verify the configuration item against requirements.
- Production systems such as: documentation, jigs, fixtures, “as built” drawings, bills of materials, and all other information needed to reproduce the configuration item.
- Supporting documentation such as: users manuals, operational guides, training materials used to train users on the operation of the configuration item.
- Process artifact data such as: traceability matrix, requirements attributes technical review notes, etc.

<u>Georgia NaviGAtor</u>

Georgia is unique in the area of CI determination because its CM program baselines field hardware, software, cabling, and documentation. The plan divides this group into three main categories: documents, drawings, and software and then further breaks those categories down to more specific subcategories, which are roughly at the same level as the Maryland and California systems. According to the CM manager, everything GDOT has in the way of ITS and IT equipment is being placed under baseline control. The manager for the NaviGAtor system is in charge of change control for all ITS equipment, and the IT equipment change control is handled by a separate GDOT agency. The NaviGAtor CM identifies all items that are currently deployed in field, as well as items that are part of inventory. The only equipment that interacts with the NaviGAtor system that is not considered a CI is equipment that is not owned by GDOT, but by outside agencies such as city and county municipalities.

Configuration Item Information

After determining what equipment falls under change control, it is important to determine the information needed to fully describe each category of items. When interviewed, some DOT personnel stated that an agency could never have too much information. Although this philosophy has its advantages, personnel and funding limitations certainly dictate a need to prioritize CI information. Thus, it is necessary for the CM manager to determine what information is critical for an agency’s daily operation.

Richmond, VA Smart Traffic Center

The configuration manager of the Richmond STC stated that he maintains at least five important pieces of information on each configuration item:

- All vendor documentation.
- Directions on how to maintain and service equipment.
- Design documents.
- Hardware layout.
- Purchase and installation date.

It should be noted that the Richmond STC does not maintain configuration item information on field devices—only on software and the related hardware (computers and communications gear).

Georgia NaviGAtor

The Georgia NaviGAtor program maintains information on all items related to its TMS, which includes hardware in the field and software. For field hardware the CM Manager maintains the following item information:

- Location.
- Identification number.
- Description.
- Make and model.

For software, each build requires three documents to be maintained:

- User manual.
- Description.
- Commenting.

The NaviGAtor program uses two software tools to manage its information. One is designed to manage the field devices; the other to manage changes in the software. According to the CM manager, each tool greatly simplifies the time necessary to store and update the information. The tools are discussed in further detail later in the report.

Configuration Identification Scheme

Georgia Navigator

The Georgia NaviGAtor configuration identification scheme is broken down into five major categories, which are determined by the CM manager. The categories and numbering conventions are:

1. Documentation: NAV01-001 – NAV01-999
2. Hardware drawings: NAV02-001 – NAV02-999
3. Forms: NAV03-001 – NAV03-999

4. Software: NAV04-001 – NAV04-999
5. Cable drawings: NAV05-0001 – NAV05-9999

Maryland CHART II System

The Maryland CHART II System similarly breaks down its configuration identification scheme into five categories. These categories are:

1. Developed applications.
2. Legacy applications.
3. COTS products.
4. Hardware.
5. Documentation.

Figure 3.2 below demonstrates the naming scheme used by the CHART II System:

Category	Identification Scheme	Example
Developed applications	[program name] [release#][build#].[version]	CHART2 R1B1.02
Legacy applications	[program name] [release#(if applicable)]	EORS2
COTS products: ➢ Operating systems ➢ Tools ➢ Applications	[product name][release# (if applicable)]	 ➢ Windows NT 4.0 ➢ ClearCase 3.2 ➢ TTS
Hardware: ➢ Network devices ➢ Servers ➢ Workstations	 ➢ [agency]-[site]-[type][#] ➢ [site][department (optional)][#] ➢ [modal letter ID][tag number]	 ➢ SHA-HANSOC-SWT1 ➢ HANSOC1 ➢ HO25455
Documentation	[task #]-[document type]-[#][revision level(if applicable)]	M361-DS-001R0

Figure 3.2 CHART II Naming Scheme

* Maryland CHART II Project Configuration Management Plan – 10/2000 (p. 3-2)

Southern California Priority Corridor

The Southern California Priority Corridor specifies the following naming scheme for configuration items:

XXXYYZZN.N

where:

XXX is the project unique identifier

YY is the CI identifier – a document and/or component identifier

ZZ is the hardware/software module identifier

N.N is the version number

Table 3.1 demonstrates some of the project unique IDs and configuration item unique Ids.

Project Unique ID	Project	CI Unique ID	CI
SHO	Showcase (Project Documents)	CO	Concept of Operations
K.3	Kernel (CSCI/HWCI) Version 0.3	UR	User Requirements
K1.	Kernel (CSCI/HWCI) Version 1.0	SR	System Requirements
TIP	TravelTIP	IS	Infrastructure Summary
IMJ	IMAJINE	UI	User Interface
MVA	Mission Valley ATMIS	IR	Interface Requirements
ICD	InterCAD	WD	Working Document (Paper)
MSF	Modeshift	AP	Architecture Paper
LVA	LA/Ventura ATIS	HL	High Level Design
FOA	Fontana / Ontario ATMIS	SD	Software Design
SDT	San Diego Region Transit Management System	DD	Detailed Design
OCM	Orange County Model Deployment Initiative (TANN)	IC	Interface Control Document
SDS	San Diego Regional Traffic Signal Integration Project	AT	Acceptance Test Plan/Procedure Together

Table 3.1 Priority Corridor Unique IDs

* Southern California Priority Corridor CM Plan – 12/5/2000 (p. 5-6)

CHANGE CONTROL

Change control is the procedure used for managing changes to the configuration of a system by evaluating a change's impact, tracing its progress, and ensuring its proper documentation. EIA 649 describes the principles behind effective change control procedures within the context of a larger CM program. Recommendations are made to help transportation professionals effectively implement change control procedures and several agencies' procedures for change control are discussed in the "Best Transportation Practices" section.

EIA STANDARD 649 DEFINITION

"Configuration change management [change control] is a process for managing product configuration changes and variances."

Change control is the process that involves (1) identifying the need for a change, (2) analyzing the impact of a proposed change on system documentation, (3) evaluating and coordinating a proposed change, and (4) incorporating an approved change into the existing system with its appropriate documentation. Changes can include virtually any modification to the system, hardware or software, depending on which parts of the system the CM activities cover. Typically, agencies that utilize CM have a specific group that is responsible for administering the change control activities including reception of change requests, evaluation of requests, determination of course of action, and assignment of responsibilities.

The purpose of change control is to ensure availability of an existing system by carefully managing change. Each change is uniquely identified to minimize redundancy and confusion. Once a change has gone through the entire change control process, the item that was changed becomes part of the new system baseline. For example, if a DOT were to see a need to modify a piece of software, the change control process would be initiated, the relevant body would decide if the change should be accepted, and the new changed version of the software would emerge as the baseline. In this process, the change request would receive a unique identifier. After modification the software also would be given a unique identifier.

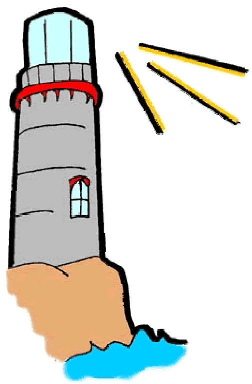
Personnel that deal with the system on a daily basis initiate the vast majority of change requests. Personnel may request a change for a number of reasons, which include:

- To fix a flaw in the system (bug fixing).
- To replace an outdated item with a newer version.
- To improve the functionality of an item.

Although it is somewhat rare, changes also may be indirectly initiated by comments from end users or a new law that requires a change in the system.

Under change management, modifications to an item are made in a systematic, measurable fashion. Typically, changes are requested by relevant personnel to the approving body, whether it is a CCB or a CM administrator. Classifications of the type of request help the approving body rank which changes should be addressed and when. Proper classification also can improve understanding of a change's impact, and therefore which CCB members should attend particular sessions. Once the authority has approved a change, they specify the parameters in which change is to take place.

IMPLEMENTATION GUIDANCE



Many important points should be considered when developing change control procedures and administration. Change control, if performed efficiently, saves time and money for the agency. This implementation guidance section is divided into three subsections:

1. Change Control Administration and Responsibilities.
2. Change Control Processes.
3. Tool Use for Change Control.

All of these areas of focus are very important to developing change control as part of a CM program.

Change Control Administration and Responsibilities

Change control administration should be one of the first tasks in developing change control. DOTs should create and use a configuration control board to make administrative decisions regarding changes to the system. Many important factors should be considered in the establishment and operation of a CCB. As with the establishment of the CM administration, it is important that as many relevant departments or sections of an agency are represented as possible to ensure that all needs are addressed. Broad representation also helps to ensure that a change proposed by one group will not adversely affect another.

In order for the CCB to operate as smoothly as possible, the tasks of each of the members must clearly be defined, and a chairperson must run CCB proceedings. In cases of disputes or extended discussions giving the chairperson the authority to make unilateral final decisions may expedite the change process. One of the most significant factors that helps a CCB run smoothly is preparing all of the members well in advance by providing a meeting agenda, which includes all of the proposed changes up for discussion. Doing so gives members adequate time to determine how the respective changes will affect their interests and to prepare notes for discussion and debate of the changes. It also minimizes the time needed to review the changes during the actual meeting.

The most important task of any CCB is reviewing and determining the fate of proposed changes. For this reason, classifying the changes into different categories based on their effect on the overall system is beneficial. Some changes may be minor enough that they do not require review by the entire CCB, but rather a subsection or even an individual member.

Chapter 6 provides in-depth discussion of CM administration.

Change Control Processes

The specifics of change control processes among DOTs vary greatly, but the same general concepts apply. It is important that groups seeking to implement effective change control use a formal procedure to ensure consistency and acceptance.

A standardized CM form is used to request a change whether it is intended to add functionality or is needed due to a flaw, a legal mandate, or regulation. Often, the form must be submitted electronically, using one of the tools discussed in the following sections. Standard information on these forms usually includes, but is not limited to:

- Requestor.
- Requestor's department/section.
- Type of change.
- Reason for change.
- Priority.
- Anticipated effects on system.

Once a change has been requested by correctly filing the proper form, a portion of the CCB or one of the outside CM experts should review it in preparation for CCB meetings.

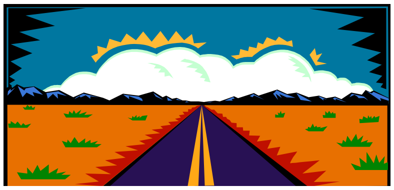
Whoever is responsible for compiling and reviewing all of the change requests should author a report to be reviewed by the CCB prior to the meetings. This provides time for CCB members to look over some of the requested changes, begin to think about their impacts, and how to implement the changes. During the meetings, each change request is discussed individually, unless grouped with a similar change request by the reviewing body. Recently, GDOT has established a change assessment and resolution (CAR) leader to present the recommended solution to the CCB. This action was taken because in some cases the solution is too complicated or out of the area of knowledge of the person requesting the change.

The CCB makes decisions about approval or rejection of change requests and assigns the job, as well as issues a due date. This information should be entered into the change control tool for tracking purposes. After the change has been initiated or completed, the CCB (or, depending on the organization, the CM manager or other staff) conducts configuration status accounting and configuration audits to ensure that the change has been executed and in a way consistent with the request.

Tool Use for Change Control

The use of tools is crucial to any DOT that is attempting to implement change control. With increasing system complexity or number of system changes, tracking and managing the change control process may become difficult if left to paper-based systems. The time personnel save in terms of change status tracking and baselining justifies the costs associated with acquisition. Change management systems account for all requested changes, their initiators, the priority of the change request, and the status of the change, and can be used to introduce new baselines. Management personnel should be provided with a tool that will guide their change control activities and track the progress of personnel on their projects.

For more information on configuration management tools, see chapter 8.



Implementation Guidance Summary

- CCBs should be established to make decisions regarding changes to the system.
- The CCB should have personnel from various departments and areas of expertise so that proposed changes may be reviewed from many perspectives.
- Agencies should use a formal change control procedure to ensure consistency and acceptance.
- After a change report is submitted, a CCB member or designated staff member should acquire and distribute the necessary information regarding the effects of the proposed change before the CCB meets.
- Tools should be used to help personnel keep track of changes in an efficient manner.

BEST TRANSPORTATION PRACTICES

This section presents a number of examples of change control and the associated procedures. The discussion is broken down into three major categories: change control administration and responsibilities, example change control processes, and tool use for change control.

Change Control Administration and Responsibilities

Georgia NaviGAtor

The Georgia NaviGAtor CM plan specifies a CCB, which is made up of DOT personnel and consultants responsible for change control decisions. The CCB must review and approve or reject all requested changes to configuration items. The CCB is not tasked with investigations or feasibility analyses. The CM manager reviews proposed changes. If a resolution is not proposed, the CM manager appoints a change assessment and resolution leader. The CCB is made up of the following personnel:

- CM manager – chairman.
- Program manager.
- IT software manager.
- Operations manager.
- Design manager.
- IT hardware manager.
- Systems integrator.
- Field hardware manager.

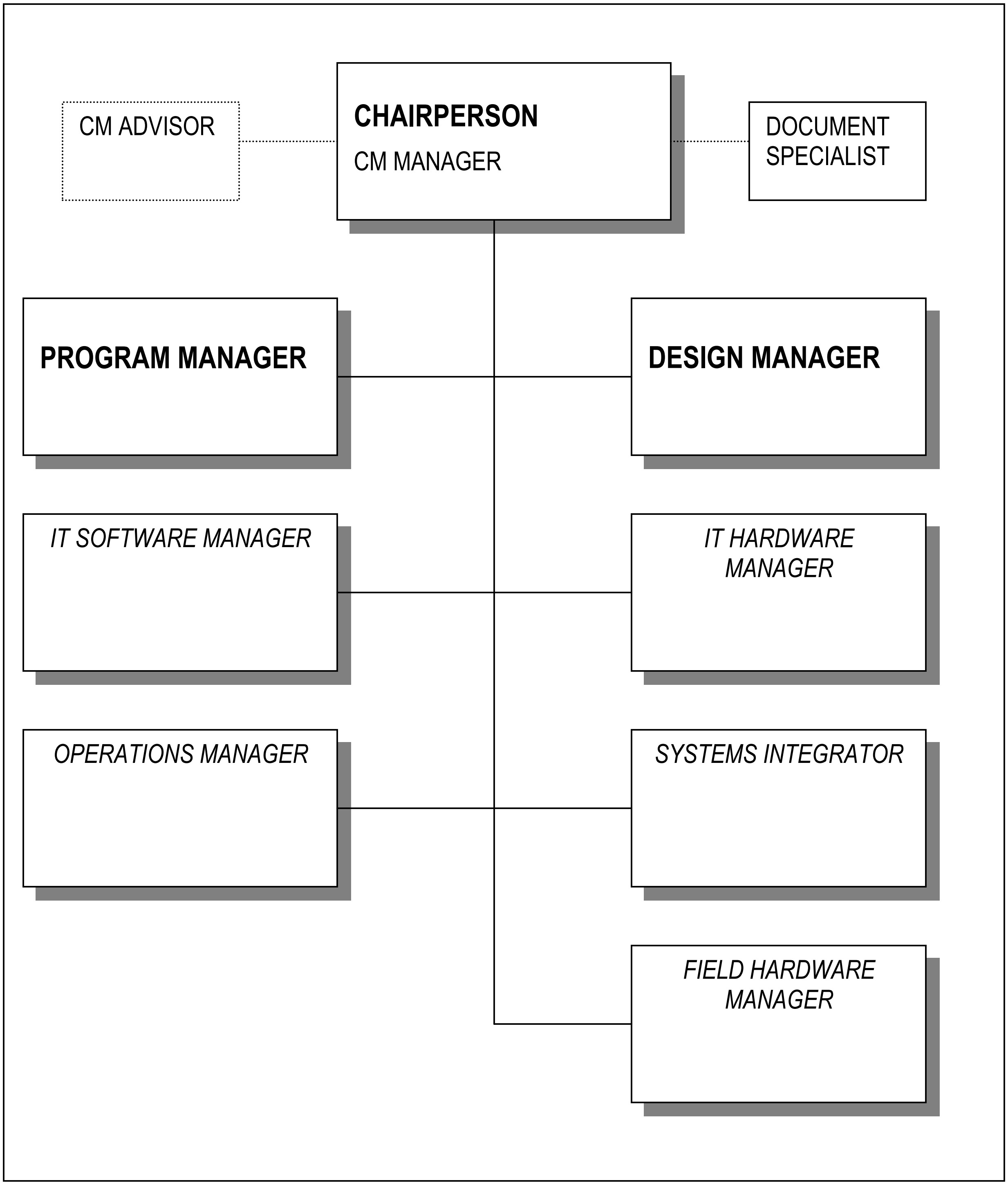


Figure 3.3 NaviGAtor CCB Organization

** GDOT NaviGAtor Configuration Management (CM) Manual NAV01-004 – 12/19/01(p. 4-2)*

CCB meetings take place regularly, normally every two weeks. Typically, the numbers of incoming System Change Request forms (SCR) helps to determine the schedule. Additional meetings may be held in cases of emergency or large numbers of outstanding SCRs. The CM manager is responsible for determining meeting times and frequency. The CM manager administers all CCB meetings. Standard meeting procedure involves the presentation of a recommended solution for each SCR either by the person that submitted it or by the CAR leader for SCRs requiring assessment. Based on the recommendation of any one CCB member, a vote is taken. If the vote is unanimous, the recommendation is approved. If not, further discussion is required until unanimous consent is reached.

Maryland CHART II System

The Maryland CHART II System relies on two major administrative bodies to regulate its change control activities: the CCB and the Level B Problem Review Board (PRB). The difference between Level A and Level B changes is represented in figure 3.4.

Level	Controlled CIs	Change Reviewers	Approval Authority
A	➢ CHART II requirements ➢ CHART II design documents ➢ Acceptance documents ➢ Transition plan ➢ Operational system components ➢ Interface control documents ➢ Other items as specified by MDSHA project manager	➢ Affected software managers ➢ Task manager	CHART II CCB (see Section 2.3)
B	➢ Development baseline items ➢ Other items as specified by MDSHA project manager	➢ Affected software managers	CHART II PRB (see Section 2.4)

Figure 3.4 CHART II Change Levels

** Maryland CHART II Project Configuration Management Plan - 10/2000 (p. 4-1)*

The CCB is responsible for establishing and enforcing the procedures regulating the change control process and its place in the CM plan. The project manager, who is considered the chairperson of the board, leads the CCB. The other members of the CCB include regional managers, a representative from the University of Maryland, a representative from the Federal Highway Administration (FHWA), a contractor task manager, a contractor development manager, and an independent validation and verification representative.

The Level B PRB meets whenever necessary to address Level B changes, which are tracked and documented by the Configuration Management Office (CMO). This board is chaired by the task manager and includes the CHART II CM office, a quality assurance representative, a system test manager, a development manager and a database designer. Members of the PRB are expected to attend meetings based on their relevance to proposed changes.

Richmond, VA Smart Traffic Center

Richmond utilizes a CCB to review and accept or reject all change requests regarding Richmond software. Its board consists of three Virginia Department of Transportation (VDOT) employees and one person from each of the two contractors that helped to develop the system. Because it is a VDOT facility, a VDOT employee chairs the CCB.

In addition to the CCB, the Richmond STC also has an issue mediation board (IMB). The purpose of this board is to resolve issues that cannot be solved by the CCB. It consists of project level management personnel and maintains the authority to determine the status of change requests should the CCB be unable to do so. This board consists of one person from VDOT (the chairman) and one from each of the contractors that worked on the system.

Various activities take place before CCB or IMB meetings. Prior to CCB meetings, the representatives of the contractors gather and process all of the Trouble Report Forms, identifying changes that could be grouped into larger software package modifications. Then they specify what changes will be implemented as a result of the larger software package change, estimate time and resources to accomplish changes, list documents affected by the changes, and submit a report specifying all of this information in time for it to be reviewed before the meetings.

The CCB is to meet regularly on a schedule determined by the chair. Presently, meetings are held on a monthly basis, and there is constant communication via email. During the meetings the CCB reviews the report generated by the contractors and may determine to accept or reject the classifications of the proposed changes. The CCB acts on system operations/maintenance issues. It does not accept or deny new large-scale projects because its CM procedures are regional, and new projects are considered on a statewide basis. The CCB also determines which software release package to issue next. Any issues that are left unresolved are passed on to the IMB, which uses roughly the same structure.

Southern California Priority Corridor

The Southern California Priority Corridor CCB is comprised of two major subcommittees: the CM Subcommittee (CMS) and the CM Technical Team (CMTT). One of the stated goals of the CCB is to ensure that CM issues are addressed during the integration of regional systems. But for other considerations, CM activities are to be handled by the individual localities.

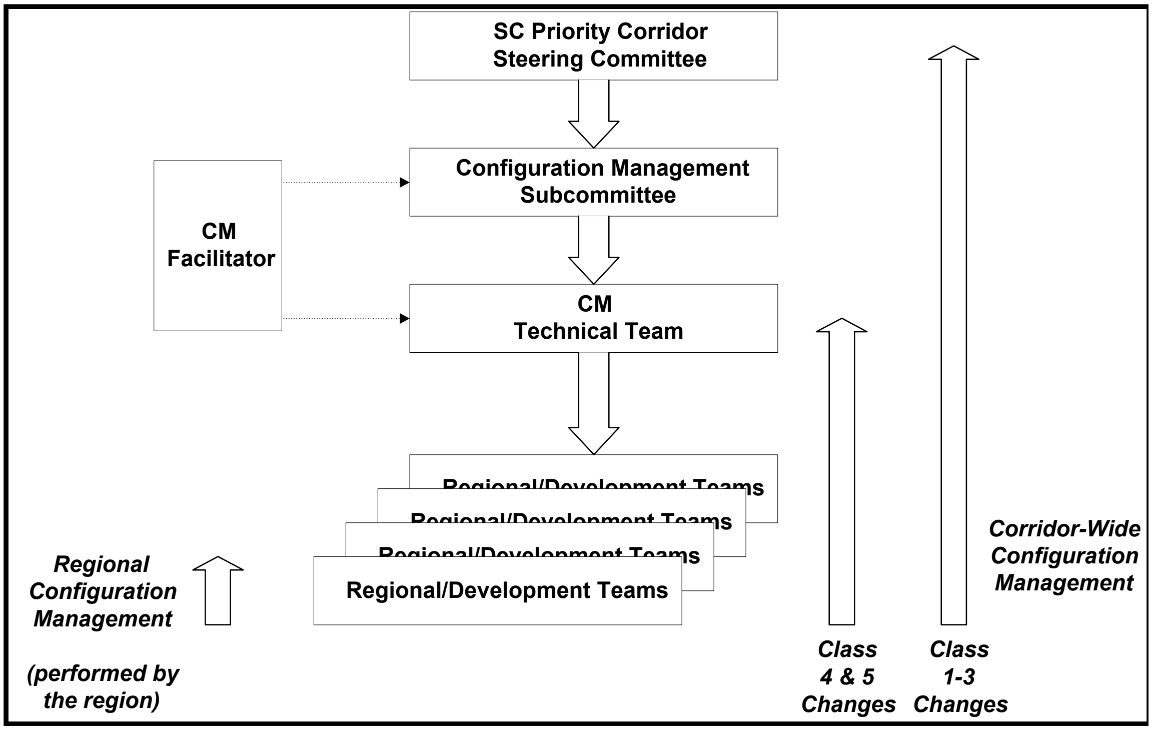


Figure 3.5 Configuration Control Board Organization

* Southern California Priority Corridor Configuration Management Plan, December, 2000 (p. 3-1)

The CMS has several tasks listed in the plan that it is expected to carry out. The most important task is to keep all member organizations up to date with the most current procedures regarding the CM program and activities. The CMS configuration is pictured in figure 3.6.

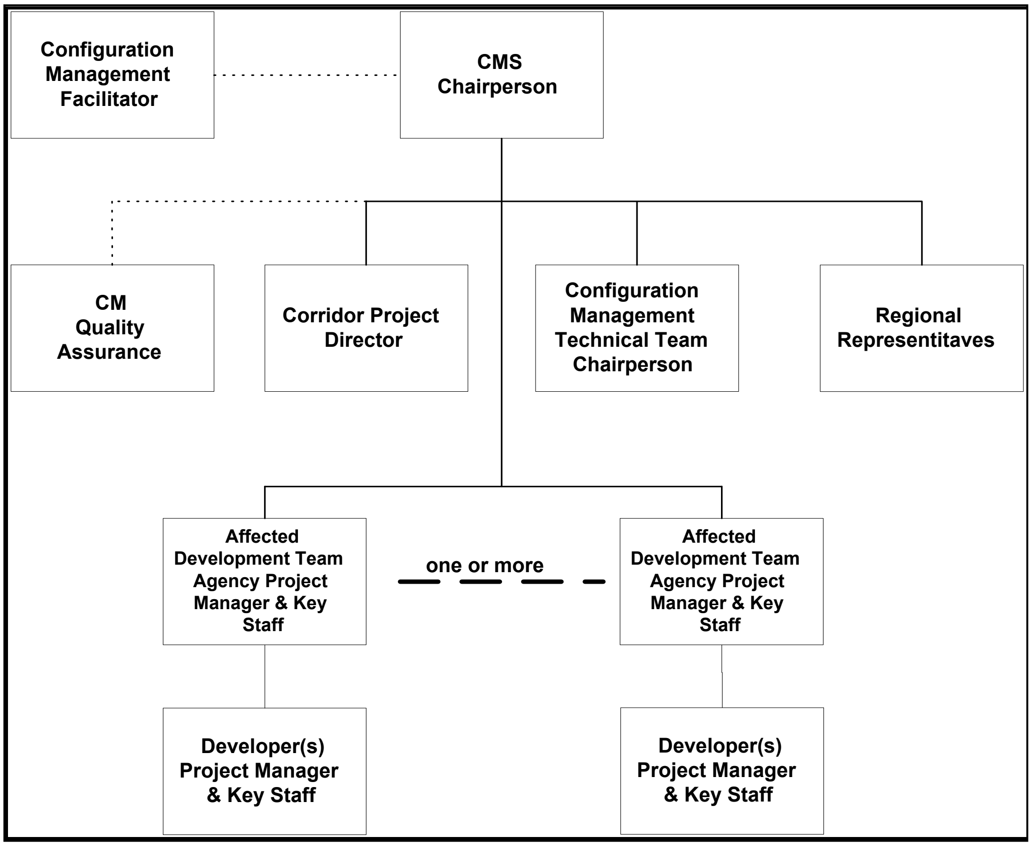


Figure 3.6 SCPC CM Subcommittee Organization

* Southern California Priority Corridor Configuration Management Plan, December, 2000 (p. 3-3)

The CM facilitator is involved with both the CM Subcommittee and the CM Technical Team and has several major duties. The facilitator is responsible for preparing both committees for their respective meetings by ensuring that all relevant materials are provided, maintaining the CM plan and standards, and facilitating and calling all CM meetings. The facilitator also must report on the status accounting and configuration audit activities.

The CMS chairperson manages the overall SCPC CM program. The chairperson must ensure the proper development of corridor-wide configuration items, oversee the development of CM policies, and verify that CM activities adhere to guidelines set forth by the SCPC Steering Committee. The chairperson also must ensure that all relevant personnel and committees have the resources and training necessary to carry out their CM duties.

The SCPC project director identifies issues that need to be addressed by the respective committees, ensures that these issues are addressed, and provides staff support for CM activities. The project director also acts as a liaison to make sure that all relevant stakeholders are involved in the CM process.

The CM quality assurance manager reports directly to the SCPC Steering Committee and must monitor and provide reports regarding all aspects of the CM process. The quality assurance manager is to report on the quality of these processes at the regular CMS and steering committee meetings. The quality assurance manager also is responsible for overseeing all configuration audit activities.

The regional representatives oversee change within their regions, send change requests to the CMS, and appeal CMS decisions, in an effort to support the corridor-wide CM activities.

Example Change Control Processes

Georgia NaviGAtor

The Georgia NaviGAtor system utilizes change control processes that apply to hardware, software, documents, and other configuration items. Georgia uses System Change Request forms to initiate such changes. Change requestors take the following steps during the life cycle of a change request:

1. A proposed change is analyzed to see whether it will alter the system configuration. If it will not, a maintenance ticket is issued. If it will, step 2 is taken.
2. The SCR is electronically filled out in its entirety; one for each requested change.
3. The SCR is checked to ensure that all of the required fields have been completed, and a log number is issued. If the SCR is categorized as an emergency, then it is brought to the attention of the program manager. The appropriate CAR leader then develops a recommended solution for presentation to an emergency CCB. When the SCR includes a viable solution, it can be placed on the agenda of the next CCB meeting. When a recommended solution is yet to be identified, the SCR is passed to an appropriately qualified CAR leader along with a due date set by the CM manager. The SCR is added to the status report and to the CCB agenda when it is ready for presentation to the board.
4. The CAR leader performs tasks such as completing necessary analysis of condition and forms, providing supporting documentation, and justifying the recommendations to the CCB. When a software range is required, the CAR leader may request that the SCR be pre-approved to permit further work to take place as part of a software build task order. The recommended solution generated by the code writer is vetted by the CAR leader and presented to the CCB as the recommended solution. Pre-approved software changes may lie on the table for some time before they are investigated and a solution developed.
5. The CM manager reviews the SCR to see whether it is a valid and complete request.
6. The document control section must document and track the release of software, documentation, and drawings.
7. Areas that are described in the SCR must verify that baselines have been updated upon the release of the document control information.
8. All changed items are reviewed and approved by someone assigned by the CCB.
9. The SCR will be closed and the CCB and SCR originator will be notified of the status.

* GDOT Navigator CM Manual – 12/19/2001 (4-9 – 4-10)

Detailed information is required to submit an SCR including:

- Originator.
- Section – the name of the section in which the originator works.

- Date.
- Subject.
- Type of change.
- Reason for change.
- Affects.
- Priority.

* GDOT Navigator CM Manual – 12/19/2001 (4-4 – 4-7)

There are 24 such fields required to complete the SCR. Typically one change is requested per form. Figure 3.7 details the SCR process for Georgia NaviGAtor.

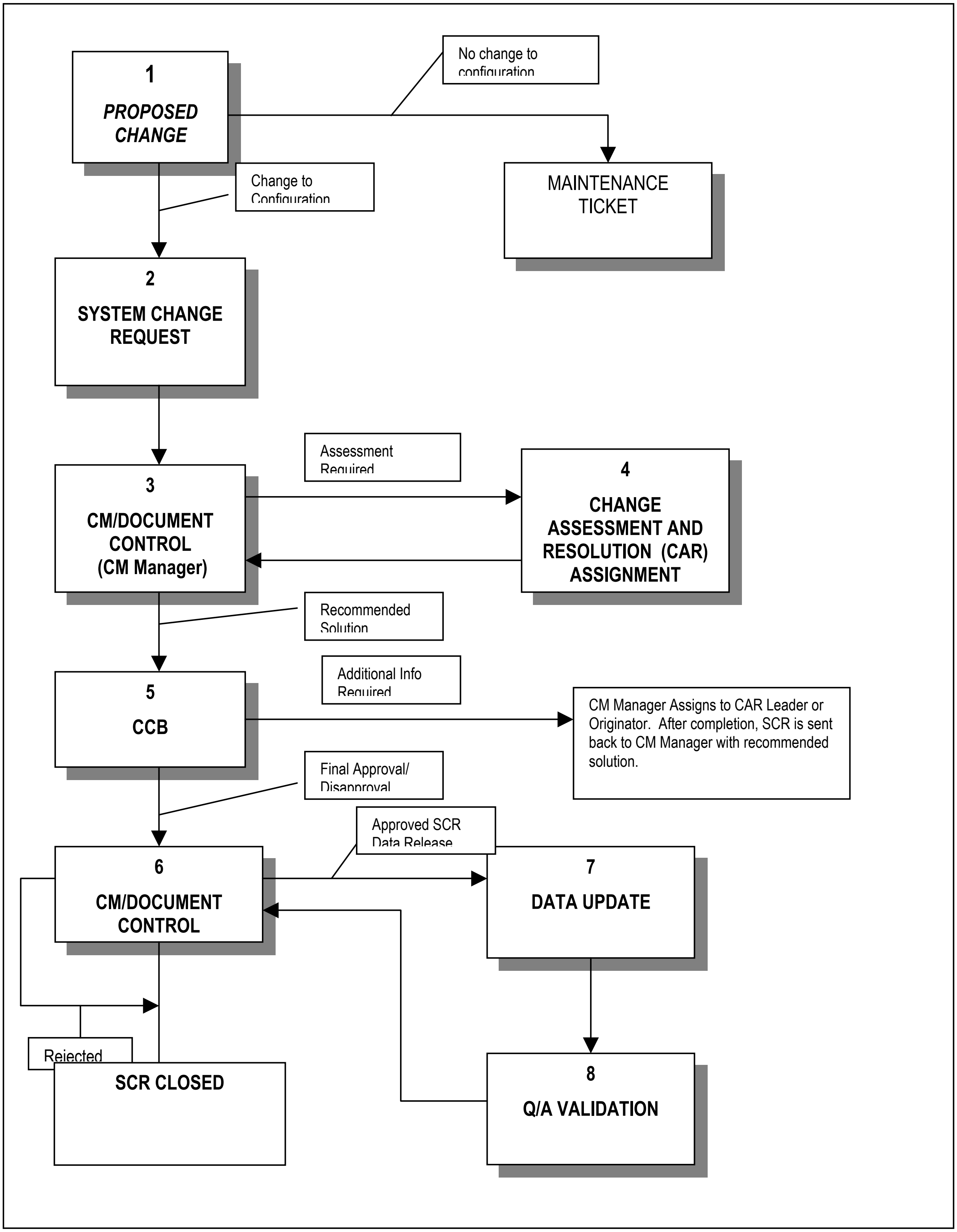


Figure 3.7 Georgia NaviGAtor SCR Flow - * **NaviGAtor CM Manual -12/19/2001 (p. 4-8)**

Southern California Priority Corridor

The Southern California Priority Corridor also uses a detailed system for change control. Their procedures apply to baselines, specifications, and manuals. Eleven steps are involved in the change control process:

1. An initiator prepares a change proposal.
2. The relevant project's engineering manager is responsible for developing the change request, which is forwarded to the CM facilitator. A package to help resolve the change is created by the team leaders. A presentation is made to the CMTT about the requested change and its impact.
3. The CMTT reviews the presentation and makes decisions about the requested change.
4. The requestor updates the Engineering Change Proposal (ECP) based on the comments made by the CMTT during the presentation.
5. A presentation is made to the CMS, similar to that given to the CMTT. The questions during this presentation are more administrative in nature, focusing on items such as scheduling and costs.
6. The requestor may make a presentation to the SCPC Steering Committee, during which questions similar those of the CMS presentation are asked.
7. Approvals may be necessary at higher levels, based on the nature of the project.
8. If approved, the requested change is implemented.
9. Full verification and regression testing is performed for the change.
10. The baseline is updated and promoted to reflect the change that has taken place to the system.
11. CM status accounting is performed to document the results of the change control process.

Maryland CHART II System

The Maryland CHART II change control process involves formal methods to propose, assess, determine the fate of, and implement changes. The process also is designed to evaluate and track the changes from initiation to completion. As a change is proposed to the respective board, it is given a priority rating based on the chart presented in figure 3.8.

Priority	Criticality	Characteristics
1 Very High	Major deficiency, error, or issue that merits immediate attention until resolved	Any one of the following is true: ➢ Critical system functionality is inhibited ➢ Testing cannot proceed in the affected functional area(s) ➢ Continuation of the situation jeopardizes the project schedule
2 High	Major deficiency, error, or issue that requires immediate attention as soon as all Very High items are resolved	Any one of the following is true: ➢ Major system functionality is inhibited, but system is not inoperable ➢ Testing can proceed in affected functional area(s) but with restrictions ➢ Continuation of the situation may jeopardize the project schedule
3 Medium	Deficiency, error, or issue that requires resolution but not immediate attention	All of the following are true: ➢ System functionality is somewhat affected, but an acceptable workaround has been identified ➢ Testing can proceed in affected functional area(s) with few or no

		restrictions ➢ The situation has little or no impact on operational use ➢ Continuation of the situation does not impact the project schedule
4 Low	Minor deficiency, error, or issue that should be resolved but may be postponed	All of the following are true: ➢ System functionality is not affected ➢ Testing is not impacted ➢ The situation (though an irritation or distraction) does not impact operational use ➢ Continuation of the situation does not impact the project schedule

Figure 3.8 CHART II Change Priorities

* Maryland CHART II Project Configuration Management Plan - 10/2000 (p. 4-1)

The CHART II change control process allows for any project staff member to propose a change to the system. The project manager reviews all incoming changes to determine if the CCB or the Level B PRB should address them. The CMO enters all proposed changes into the appropriate software tool in preparation for this review. Level A changes initially are reviewed by a small external CCB or personnel relevant to the change, which then make recommendations to the full CCB that will determine the fate of the proposed change. The change control process is represented in figure 3.9.

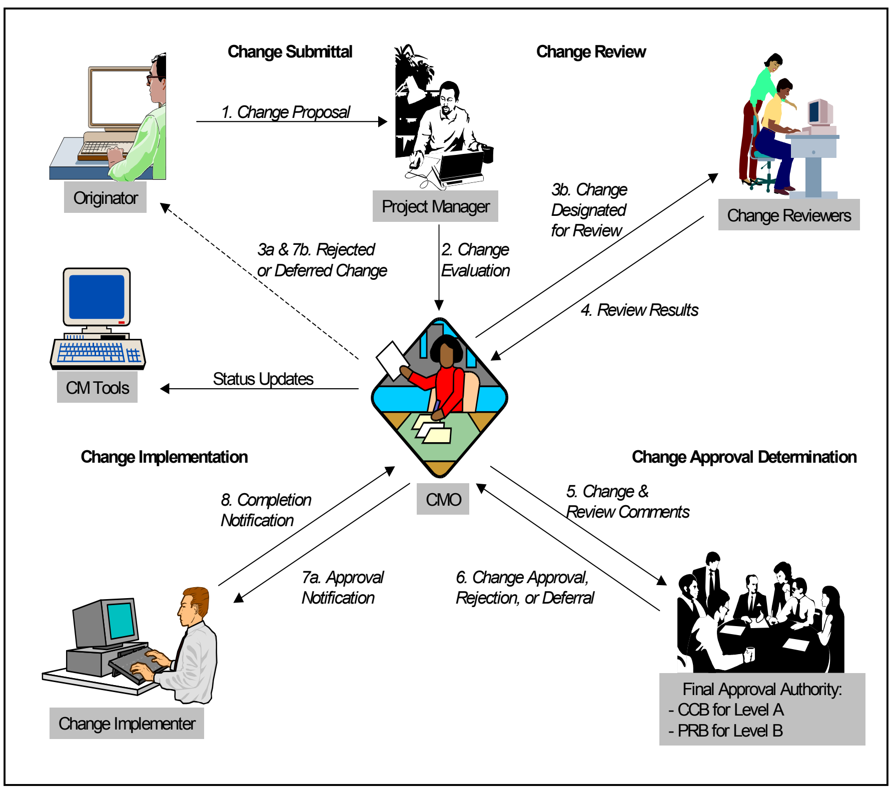


Figure 3.9 CHART II Change Control Process

* Maryland CHART II Project Configuration Management Plan - 10/2000 (p. 4-3)

As part of the change control process, the CMO undertakes several actions based upon the determination of what will happen with the proposed change by the respective body. Such actions are listed in table 3.2.

Approval Determination	CMO Action Taken
Approved	Updates the corresponding record in the applicable tool Notifies the originator of approval Forwards the approved package to the individual assigned to implementation Continues to track implementation progress
Rejected	Updates the corresponding record in the applicable tool Notifies the originator that the item has been rejected and provides the reason(s) for rejection
Deferred	Updates the corresponding record in the applicable tool Notifies the originator that the item has been deferred and will be reevaluated on a specified date May request that the originator provide further information or conduct further testing

Table 3.2 CHART II CMO Actions

* Maryland CHART II Project Configuration Management Plan - 10/2000 (p. 4 -4)

Richmond, VA Smart Traffic Center

The software CM plan for the Richmond STC specifies a number of specific change control processes. Under its procedures once a system user identifies a problem, the user is to fill out a trouble report form, which is pictured as figure 3.10. Trouble Report Forms also may be used simply to recommend enhancements. This form requires certain information about the nature of the change request, such as reasons and subsystems that the change may involve. The trouble report form is forwarded to the consultants who helped develop the system. The consultants review the form and determine the seriousness of the possible changes. Eventually, the CCB makes a determination of the status of the change request and classifies it as an enhancement, a bug, or a change. The Richmond STC plan includes a detailed flowchart, dictating which steps should be taken at this stage.

Trouble Report Form

for

Richmond STC

Name ______________________________ **Date** ____/____/____
Short Title ____
Functional Area (circle one)

CCTV	VMS	HAR	TSS	GUI
Incident Mgmt	Work Zone	ITS Schedule	Incident Mgmt	Other ______________

Description of Problem or Requested Change:

____
____
____
____
____
____
____
____
____
____
____
____

Issue Type (Circle one)	**Software**	**Hardware**	**Documentation** **Unknown**
Classification (Circle one)	**Bug**		**Enhancement** **Change** **Unknown**
Priority (Circle one)	**Low**		**Medium** **High**
Screen Prints Attached	**Yes**		**No**

Figure 3.10 Richmond Trouble Report Form

* Richmond CM Plan – 12/1/2001 (Appendix A)

Tools Use for Change Control

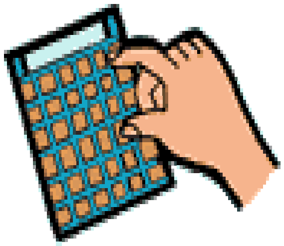
Georgia NaviGAtor

Georgia uses a software package tool called a change management system to help manage its change control procedures. The tool accounts for all requested changes, their priority, and their originator, and tracks the change request as it goes through the change control process. The CM manager can use this tool to help assign software change responsibility, track the status of the change, and then reintroduce it as a new baseline. The primary mission of the change management system is to control and integrate software changes. Information taken directly from the SCR form is entered into this tool in order to authorize the release of software.

Richmond, VA Smart Traffic Center

The Richmond STC uses the Client Portal Help Desk, an online issue database, for its change control applications. This online interface collects all of the change requests that are to be processed in the coming period. The change requests are entered and tracked using a feature called the Change Desk. The status of changes that have been approved is visible to the users, and the tool also can assign new changes to personnel. Because it is a Web-based tool, any project member may access it to determine the status of changes and change requests.

CONFIGURATION STATUS ACCOUNTING



Configuration status accounting is the element of the CM process that involves recording all relevant information about configuration items and the CM program as the system undergoes changes. One of the primary objectives of CSA is to update an item's documentation to reflect the most recent changes and the current configuration of that item. CSA is closely linked with change control and helps to ensure that each change has been properly documented. The primary output of the CSA process is current, accurate information, which will facilitate future changes to a particular item or to the system. In this section, a description of configuration status accounting based on EIA 649 is presented, implementation guidance is provided, and examples of best transportation practices are described.

EIA STANDARD 649 DEFINITION

"*Configuration Status Accounting (CSA) correlates, stores, maintains and provides readily available views of the organized collection of information. CSA provides access to accurate, timely information about an {item} and its documentation throughout the {item's} life cycle."*

CSA is a method for organizing the information about an item and the changes it goes through and helps ensure that the documentation and other materials regarding an item have been updated. According to EIA 649, CSA deals with the storage and maintenance of:

- Information about the configuration documentation.
- Information about the item's documentation.
- Information about the item's operational and maintenance documentation.
- Information about the CM process.

Some of the primary objectives of CSA include allowing access to information about change control decisions, supporting system inquiries such as design problems, and providing total information about a configuration items. CSA allows the TMS to backtrack information to discover the source of problems or issues that may arise operationally.

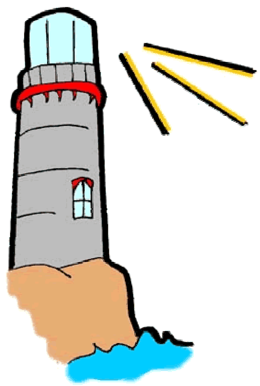
Throughout an item's life cycle, all pertinent information about it should be recorded and catalogued using a system that supports data organization and allows easy retrieval of data. Specific information to be recorded is chosen typically by personnel responsible for CM management. EIA 649 cites six phases of an item's life cycle that serve as subdivisions for information gathering on that item. The information from all prior phases should be used in the current phase. The six phases are:

1. **The Conception Phase** – Information about item functional requirements is recorded using the CSA procedures.
2. **The Definition Phase –** As the item is developed, information such as design documentation and engineering drawings is catalogued. Essentially, any document used to design, develop, test, build, or verify an item is recorded. If the design is changed significantly during development, documentation recorded during CSA will account for these changes. This phase typically requires the largest amount of information.

3. **The Build Phase** – CSA information that is recorded during this phase includes differences between the implemented item and the design. Also, the serial numbers of components and dates associated with various milestones of the build are recorded.
4. **The Distribution Phase –** Information during this phase involves the installation configuration and dates associated with installations and warranties.
5. **The Operation Phase** – During operations changes that are made to an item because of upgrades or maintenance are recorded and catalogued. All of the information dealing with change control of an item is maintained in this manner.
6. **The Disposal Phase** – During this phase any information about the disposal of an item, such as salvage options or disposal contracts, is recorded.

CSA usually involves the recording of information in a database, sometimes referred to as the CSA information management system. The information should be gathered from multiple sources—from engineers to management.

IMPLEMENTATION GUIDANCE



CSA is extremely important to a CM program because it helps verify that that the procedures specified for configuration identification and change control are implemented as intended and performed effectively. Decision makers must have the most accurate information possible on the state of the TMS. For this reason it is important to have:

1. Effective CSA activities.
2. Detailed CSA reports.

The CSA activities and the reports they generate go hand in hand, but are discussed separately.

CSA Activities

CSA activities are very similar across DOTs. The primary objective of most CSA activities is to record and track changes to configuration items. As an item is introduced into a system, it should become part of the CSA process. Any proposed, ongoing, or completed change to that item should be recorded with detailed information in such a way that the information is easily retrievable. Using as much detail as possible, the CSA activities should highlight any differences between the proposed change and the implemented change so that decision makers can understand the deviation.

The use of software tools for execution of CSA activities is recommended. Tools allow personnel involved with the system to enter data about items or changes to items into a central database that is viewable by all with access. Having an on-line tool or a database application allows management to review changes on a system-wide level without reading through pages of documents.

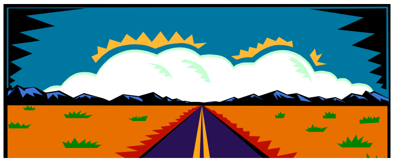
For more information on configuration management tools, see chapter 8.

CSA Reports

CSA reports are the results of CSA activities and are the final product that management often uses to assess their systems. Various DOTs use different levels of detail and require different types of information for their reports. The format of CSA reports often is affected by the systems used for configuration identification or change control. While information may vary from report to report, some information about configuration items is essential to effective CSA, including:

- Identification information.
- Change history.
- Current status.
- Proposed changes.

These basic pieces of data help to facilitate the CSA process. But decision makers also typically add fields for additional information that would find useful.



Implementation Guidance Summary

- All changes should be recorded with detailed information, which can be used to determine whether the change was implemented according to design.
- A robust software tool should be used in carrying out all CSA activities.
- CSA should highlight any differences between a proposed change and the change as implemented.
- CSA reports should be used to assess the current status of a system.

BEST TRANSPORTATION PRACTICES

This section presents a number of examples of configuration status accounting processes and the documentation they require. DOTs utilize various levels of CSA based on their needs.

CSA Activities

Southern California Priority Corridor

The Southern California Priority Corridor plan specifies a robust system for configuration status accounting. The plan keeps standardized records of the most current versions of documents, configuration items and their related parts, and current configuration item identification numbers. When an item is first placed under CM, the process is initiated and information is updated throughout the life cycle of the item. The stated goal of the CSA system is to:

1. Monitor and track documentation.
2. Report administrative activities.
3. Track action items.
4. Record audit results.
5. Maintain listings of items.
6. Track verification results.

These activities are intended to help decision makers understand the status of their systems to help them make informed decisions.

Richmond, VA Smart Traffic Center

The Richmond Smart Traffic Center CM plan specifies that the CSA activities be carried out using a Web-based database tool to record change documentation. Management personnel can query the list of requested changes to see how many are outstanding, the priority of the change, and the anticipated schedule. As changes are carried out, the contractors that work with VDOT are expected to update the Web-based tool to reflect the new status. As a change is completed, its status will change from "approved" to "completed", after which the change information will be available to VDOT management.

Maryland CHART II System

The Maryland CHART II System uses a CM plan that calls for specific procedures for CSA. The stated goals of their CSA activities are to record and monitor changes to configuration items. Each proposed change is identified and tracked, and its status is reported throughout the life cycle. One important purpose of its CSA system is to analyze the impact of changes on project activities or on the overall system. Using the reports generated by CSA, decision makers can evaluate the quality of system testing, system documentation, and personnel training.

CSA Reports

Southern California Priority Corridor

The Southern California Priority Corridor plan specifies a number of reports that are associated with CSA activities. The Specification Change Notice (SCN) tracks revisions to an item's specifications and records basic information that is used to track an item from the current release to the SCN. Detailed information also is recorded of drawings of system components. Some data that is included for this documentation includes drawing number, drawing title, and revision number. Similar reports are kept about the following:

- Software version level and history.
- CI component listing.
- Change documentation tracking.
- System problem/change report status accounting.
- CI deliveries.
- Review of action items.

For each of these divisions of CSA, similar information is recorded and maintained to provide decision makers with the information necessary to resolve issues.

Georgia NaviGAtor

The Georgia NaviGAtor plan specifies a system for CSA that is focused on CM activities. The three major reports that are to be generated by the CM manager and provided to the CCB are:

1. SCR status reports
2. SCR analysis reports
3. Audit reports

The SCR status reports provide a log of all SCR activities, reflecting such information as priority, subject, status, and dates. The SCR status reports should be updated and made available to all CCB members on a regular basis. The SCR analysis reports provide information on all of the SCRs over a reporting period and is typically issued very three months. This report should include information such as numbers of SCRs and number of open/closed SCRs. Audit reports are generated by the CM manager within five days of an audit, providing such information as areas audited, criteria, and results. *(NaviGAtor p. 3-13)*

Maryland CHART II System

Table 3.3 lists the reports generated and entered into the CM software tool for the Maryland CHART II System.

Report Title	Content Description
CI List	List of all CHART II CIs with version identifiers and cross-references to associated change records
Baseline Documentation	List of currently approved versions of controlled CHART II project documentation by number and title, with cross-references to associated change records
CM Audits	List of held and planned FCAs and PCAs by date, with status and cross-references to associated CIs, change records, and baseline documentation
Change Records	List of all CHART II change records by number, date, and title, with status and cross-references to DOORS change records, affected CIs, and baseline documentation
D/Ws (Deviations/Waivers)	List of all CHART II D/Ws by number, date, and title, with status and cross-references to associated CIs and baseline documentation
Software Lines of Code Counts	Tool-generated lines of code for all baseline units divided into data set instructions (DSI), comments, and blanks
System Problem Report Summaries	Table of all pending and/or closed CHART II system problems, at levels A and B, and their status, posted to the CHART II web site

Table 3.3 CHART II CSA Reports

* Maryland CHART II Project Configuration Management Plan - 10/2000 (p. 5-1)

CONFIGURATION AUDITS

The term “audit” traditionally is thought of in the context of financial statements. Configuration auditing is based on the same fundamental concept. It is a process that confirms that the documentation for each CI is consistent with the item and ensures adherence to the procedures specified in the CM plan and program. EIA 649 lists in detail the goals of configuration audits and the resources that should be used. Recommendations are made to effectively employ configuration audit procedures, and best transportation practices are listed as examples of these recommendations.

EIA STANDARD 649 DEFINITION

"Configuration audits establish that the performance and functional requirements defined in the configuration documentation have been achieved by the design and that the design has been accurately documented in the configuration documentation."

Configuration audits are used to confirm that designs or documentation achieve its goals by systematically comparing the requirements with results of tests, analyses, or inspections. They are thorough examinations of CIs, comparing the associated documentation and change records that provide a history of the item to ensure that the documentation reflects the current state of the CIs. One of the primary objectives of conducting configuration audits is to verify that the documentation for items is consistent with the items themselves. Audits are carried out in order to assure that the change control procedures that are in place are effective and are being used and that the documentation reflects actual changes. Audits typically are carried out by the organization or by an independent contractor.

EIA 649 states that a body relevant to specific systems should determine procedures for auditing and verification of those systems. For example, when conducting an audit on a database system, the auditor or auditing body should be involved with the database system or have significant knowledge of it. Measures of effectiveness of configuration audit standards likewise are determined. They must be consistent within a CM program. For this reason audit plans must be developed prior to audit and agreed upon by the relevant bodies. According to the standard, the following information should be recorded during audits:

1. Any questions the auditor has about an item or CM procedures.
2. Discrepancies or anomalies between documentation and actual configuration.
3. Recommended courses of action.

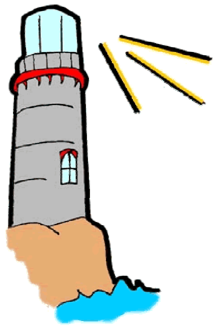
EIA 649 also lists a number of resources that are useful or necessary for conducting configuration audits, including:

- Audit plan – The audit plan should be established before the audit begins with an agenda, personnel, procedures, and a listing of what specific configuration items are intended for audit. Such a plan also verifies whether personnel are following appropriate procedures. If procedures that personnel are required to follow are part of the audit, they should be identified.
- Audit personnel – Audit personnel should be specified based on expertise in the area intended for audit.

- Relevant documentation – The relevant documentation for audits should include design documents, identification information, and change history.
- Tools such as software applications or matrices that track items – Tools should be used to help verify that the design is consistent with the existing documentation.
- Access to configuration items.

The end results of the configuration audit process should verify that the identification, change control, and status accounting procedures have been used as intended. If not, the audits help determine areas where the procedures or CM program need reinforcement for compliance, modification, or improvement. The audit process helps provide a thorough review of all of the configuration items and ensures that the most up-to-date documentation of the CI status is available. This procedure also identifies some of the items that will need to be fixed or modified to reflect design requirements.

IMPLEMENTATION GUIDANCE



The goals of configuration audit procedures are clear: to ensure that documentation is consistent with the system configuration, to examine current baselines, and to ensure that the changes made to a system were properly requested, approved, and carried out. An effective configuration audit procedure should verify that the other components of CM (configuration identification, change control, and configuration status accounting) are working properly or identify problems in any of these procedures.

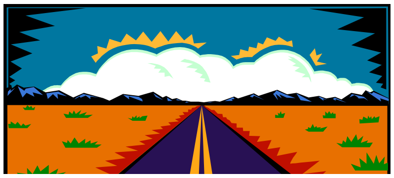
Configuration Audit Activities

Effective configuration audit activities should take place on a regular basis with the possibility of additional audits added as necessary. The CCB should determine which parties are responsible for auditing which parts of the system, as well as the frequency of audits. Usually, agencies have the CM manager or an outside consultant that helped develop the system conduct configuration audits. Having either or both of these personnel audit the system is beneficial because both have an intimate knowledge of the CM plan and know the requirements of the system. The purpose of such audits should be to verify that configuration documentation is consistent with item configuration and that changes to items were requested, approved, and baselined in a manner consistent with the CM plan. Audits also should be conducted to ensure that various departments or offices within an agency are adhering to the procedures defined in the CM manual.

Based on the findings of the audits, the auditor(s) should be responsible for filling out all relevant forms or reports or updating any other audit documentation. Usually, these forms are an audit report and any change request forms that are needed to conform to system requirements as detailed in the CM plan. This information should be presented to the CCB for review and determination of further action. For any changes deemed necessary during the audit, the auditor should fill out documents to initiate the change and deliver it to the CCB for action.

Configuration Audit Resources

A limited number of resources are required to execute effective configuration audits. The CM plan should define specific roles and responsibilities for personnel involved with the auditing process. Ideally, a procedure for conducting the audits also is defined, perhaps as a separate document. Audit checklists can greatly facilitate the process and help ensure that audits are conducted consistently each time. The audit findings often necessitate changes, which require either the standard change forms or forms specifically tailored to changes consequent to configuration audits.



Implementation Guidance Summary

- The appropriate personnel as chosen by the CCB should conduct configuration audits on a regular basis in order to ensure that the adopted CM policies are being used.
- The auditor is responsible for documenting the findings and initiating the necessary changes.
- Audits should be conducted in a standardized environment, which describes the auditor's responsibilities and supporting paperwork.

BEST TRANSPORTATION PRACTICES

This section presents a number of examples of configuration audit procedures used in transportation CM programs. The discussion is broken down into two major categories: configuration audit activities and configuration audit resources.

Configuration Audit Activities

Georgia NaviGAtor

The Georgia NaviGAtor plan calls for two major types of audits within the CM Program: GDOT section audits and CM manual audits. The CM manager and the CM advisor regularly audit sections (departments or subdepartments) within the GDOT organizational structure to ensure that groups within the department are adhering to the CM program and plan. These audits are conducted at least on a quarterly basis for each section. The section manager receives notice well in advance of the audit as well as an agenda from the CM manager. Activities involved with the GDOT section audits include:

- Ensuring that all documentation, software, etc. has been updated per approved SCRs.
- Reviewing current existing baselines.
- Comparing internal processes to standard operating procedures.
- Establishing new procedures for CM manual and standard operating procedures.
- Creating SCRs for any changes to CM manual.

The NaviGAtor CM plan also calls for audits of the CM manual. The CCB regularly examines the content to ensure that it is applicable to the current situation and system configuration. Based on any discrepancies identified by the audits, the CCB recommends new procedures or changes to existing procedures to the CM manager, who subsequently creates SCRs for any changes to the CM manual.

Southern California Priority Corridor

The Southern California Priority Corridor CM Plan calls for both informal and formal audits of the system. Typically, the CM quality manager is responsible for ensuring that the audits take place and for determining what members of the CM team are to conduct them. The overall project office is responsible for audits of corridor-wide CM items.

Under the informal audits, the baselines and the CM library are regularly examined to ensure that documentation and item status coincide. These audits are conducted both internally and by sources external to that particular part of the system. Another primary goal of the informal audits is to verify that contractors and vendors are adhering to the CM program. Informal audits are agreed to in advance, and the relevant parties know the agenda prior to the audit. Informal audit results are reported directly to the CMS chairperson. Occasionally, audits may be conducted of contractors working on the project. In such instances results are documented and provided to the CMS and the contractor management staff.

SCPC formal audits are more structured and defined. The quality manager conducts both functional and physical configuration audits of the system. The goals of these activities are to confirm that the documentation for CIs is consistent with their current configuration and to establish new baselines for items if needed. These audits are required to approve new baselines or prior to the installation of new hardware.

The CM quality manager determines a schedule to review and audit CM activities for quality assurance purposes. The following reports describe three major items:

1. Compliance with CM standards and procedures.
2. Performance of periodic informal CM audits.
3. Performance of periodic software baseline audits.

** Southern California Priority Corridor Configuration Management Plan, December, 2000 (p. 9-2*)

Maryland CHART II System

The Maryland CHART II Project Master Plan outlines procedures for both functional configuration audits (FCAs) and physical configuration audits (PCAs). FCAs are conducted for delivery of every item prior to customer acceptance to determine whether test results indicated that the system meets its functional requirements and to verify that the documentation for CIs is updated and accurate for the current configuration. FCAs use a set procedure, which is defined in the FCA Procedure documentation, and they are conducted simultaneously with the PCAs. The purpose of the PCAs is to confirm that a CI is consistent with its documentation and that only requested and approved changes were executed on the item.

Configuration Audit Resources

Configuration audits require the fewest amount of resources of any of the CM activities for most agencies using CM. Most agencies have documentation, which outlines some of the procedures that are to be used in the audits, and forms, which are to be completed prior to and upon completion of configuration audits.

Georgia NaviGAtor

The NaviGAtor CM manual requires the submission of formal reports to the CCB after completion of an audit. The report serves as the basis for the initiation of change request forms, which help the system conform to the requirements of the CM manual. If the requested change ultimately leads to a modification of the CM manual, then a change request must be filed and reviewed by the CCB in order for that change to take place.

Southern California Priority Corridor

The Southern California Priority Corridor CM plan specifies a list of materials to be involved in the configuration audit process, such as:

- An audit plan.
- An agenda for particular audits.

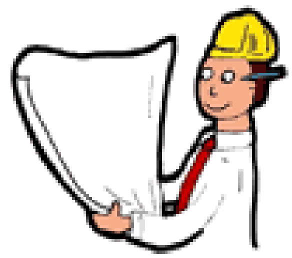
- Applicable CIs.
- Documented audit results.
- Audit tools such as software.
- Copies of reports and data sheets.

The findings of these audits are distributed to audited participants and other parties in formal reports.

Maryland CHART II System

The Maryland CHART II CM Plan requires a number of documents for its configuration audit processes. For FCAs the plan requires an FCA procedure document and FCA checklist, which assigns responsibilities for audit activities. Likewise, PCAs require procedure documents and checklists, which have similar goals.

CHAPTER 4 -
Configuration Management Plan



The Configuration Management plan is the defining guidebook for a CM program. It defines all of the procedures, organizational responsibilities, and tools to be used within the CM process. The plan is the backbone of a CM program, and as such, must either include well-developed, detailed procedures or refer to their locations in other documents. Following a general description of CM plans from EIA 649, this chapter provides implementation guidance and best transportation practices as examples of these recommendations.

EIA STANDARD 649 DEFINITION

"A CM Plan describes how CM is accomplished and how consistency between the product definition, the product's configuration, and the CM records is achieved and maintained throughout the applicable phases of the product's lifecycle."

A CM plan clearly describes how CM is accomplished and how consistency between a system's configuration and the configuration records is achieved and maintained. The CM plan is a central source of information for the CM program. According to EIA 649, key benefits of creating a CM plan include:

- Assurance that the appropriate CM processes are applied.
- Detailed descriptions of responsibilities for CM activities.
- Accurate knowledge concerning required resources.
- A foundation for continued improvement.

EIA 649 discusses in detail the requirements of the plan and considerations that should be taken into account in its development. A CM plan should not be a one-size-fits-all document. Rather, it must be tailored to meet the needs of the agency responsible for CM. In particular, EIA 649 points out that a well-developed plan will aid in the training of personnel in CM and will help explain the process to outside personnel, such as upper-level management and auditors.

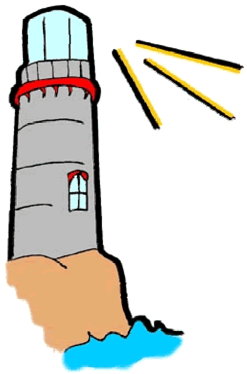
Key topics that EIA 649 states should be addressed by a CM plan include:

- General {system} definition and scope.
- Core CM process procedures.
  - Configuration identification.
  - Change control.
  - Configuration status accounting.
  - Configuration audits.

- CM management.
- Organization, roles, and responsibilities.
- Programmatic and organizational interfaces.
- Definitions of terms.

If these topics are covered in detail in the plan, the CM program will have a sound blueprint to guide its effective implementation. It also is important to note that the size of the CM plan should not be so large as to intimidate users; some specialists have found that large documents tend to convey a perception of large bureaucracy. If the procedures are sizeable, they should be segmented out into their own documents to reduce cultural resistance.

IMPLEMENTATION GUIDANCE



The CM plan is essential to establishing and maintaining an effective CM program. This reflects the fact that the mechanics of the CM process mean very little if they are not tailored to the specific TMS. Under no circumstances should a transportation management system attempt to institute a CM program without first developing a CM plan.

Why a CM Plan?

Performing CM for the sake of CM becomes a cumbersome, time-consuming process, which does not result in benefits. A concerted effort to tailor the process to the TMS must be made by using a CM plan.

A recent survey of transportation professionals involved in CM identified the following key benefits of a CM plan.

- The plan documents the CM process and as such acts as the tool used to gain project and management support for the process.
- The plan forces an agency to define and describe the process.
- The plan causes the agency to think about what it will do and how it will do it.
- The plan serves as a contract vehicle for the project (in some cases).

Where to Begin

First, recognize that the development of an effective CM plan for a transportation agency is not a turnkey job that can be completely handed over to a consultant. Although most agencies surveyed have used a consultant to support CM plan development, they agree that it is essential to have agency staff actively involved with, or leading the development of, the plan because agency staff has the best understanding of the system functionality and change control needs.

Given the active role required of a transportation agency in plan development, the next step is to become educated. Staff must understand the principles and concepts of CM. The training opportunities detailed in chapter 10 provide examples of available courses. In addition this guidance document may be used for educational purposes.

For more information on configuration management training, see chapter 10.

An excellent guidance document specific to CM plan development is *CM Plans: The Beginning of your CM Solution* (Bounds and Dart, 2001). This document is available on-line at the Software Engineering Institute's Web site at

http://www.sei.cmu.edu/legacy/scm/abstracts/abscm_plans.html

Much of the guidance provided in this document is derived from the Bounds and Dart report. Individuals involved in CM plan development are advised to obtain a copy of this report for further guidance.

Most transportation professionals currently involved in CM did recommend using outside consultants to support the development of the CM plan. Consultants helped minimize the disruption of normal operations and allowed the CM managers for the various agencies to spend as little as a few hours a week on plan development. For some of the larger CM programs, consultants worked full time for up to a year developing the system and procedures that would be used, while a number of agency staff worked part time on CM throughout development.

Many agencies also cited the importance of using industry standards in the development of the plans, organization, and procedures that are to be used in the CM program. Some used the standards as the primary resource in the development of the plans.

Developing the Plan

Developing a CM plan is not a mysterious, magical process. Rather, it simply requires concerted effort and communication to ensure that the plan meets the needs of the TMS in question. This subsection summarizes the steps recommended by Bounds and Dart.

1. Start with a standard. A number of good standards to guide CM plan development are available. The Bounds and Dart document includes a comparison of some of the more popular plans. In particular, the IEEE Standard for Software Configuration Management Plans (IEEE Std 828-1990) is recommended.
2. Create a template. Create a template/outline for the plan, which will guide deliberations in next steps.
3. Develop CM procedures. Develop the various procedures that the organization will follow in the CM program using the template as a guide. Doing so is by far the most difficult step in the process. It also will require involvement of individuals with expertise in the TMS as well as CM. Essentially, the team must study various procedures to find ones that will work for the agency.
4. Document. Document the procedures and other plan material developed in step 3.

What Should Be in the Plan?

The outline provided by Bounds and Dart is an excellent example structure of a CM plan.

1.0 INTRODUCTION
- 1.2 Scope
- 1.3 Definitions
- 1.4 References
- 1.5 Tailoring

2.0 SOFTWARE CONFIGURATION MANAGEMENT
- 2.1 SCM organization
- 2.2 SCM responsibilities
- 2.3 Relationship of CM to the software process life cycle
  - 2.3.1 Interfaces to other organizations on the project
  - 2.3.2 Other project organizations CM responsibilities

3.0 SOFTWARE CONFIGURATION MANAGEMENT ACTIVITIES
- 3.1 Configuration Identification
  - 3.1.1 Specification Identification
    - oLabeling and numbering scheme for documents and files
    - oHow identification between documents and files relate
    - oDescription of identification tracking scheme
    - oWhen a document/file identification number enters controlled status
    - oHow the identification scheme addresses versions and releases
    - oHow the identification scheme addresses hardware, application software, system software, COTS products, support software (e.g., test data and files), etc.
  - 3.1.2 Change Control Form Identification
    - oNumbering scheme for each of the forms used
  - 3.1.3 Project Baselines
    - oIdentify various baselines for the project
    - oFor each baseline created provide the following information:
      - oHow and when it is created
      - oWho authorizes and who verifies it
      - oThe purpose
      - oWhat goes into it (software and documentation)
  - 3.1.4 Library
    - oIdentification and control mechanisms used
    - oNumber of libraries and the types
    - oBackup and disaster plans and procedures
    - oRecovery process for any type of loss
    - oRetention policies and procedures
      - oWhat needs to be retained, for whom, and for how long
      - oHow is the information retained (on-line, off-line, media type and format)
- 3.2 Configuration Control
  - 3.2.1 Procedures for changing baselines (procedures may vary with each baseline)
  - 3.2.2 Procedures for processing change requests and approvals-change classification scheme
    - oChange reporting documentation
    - oChange control flow diagram
  - 3.2.3 Organizations assigned responsibilities for change control
  - 3.2.4 Change Control Boards (CCBs) - describe and provide the following information for each:
    - oCharter
    - oMembers
    - oRole
    - oProcedures
    - oApproval mechanisms

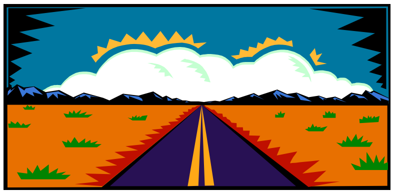
The Plan is a Living Document – It Will Change Too

The CM plan documents an agency's CM program. As the program progresses, the plan will need to change to reflect the changing environment. In addition, as a transportation agency gains experience in CM, this experience will dictate changes to the plan. A one CM official stated, "The old adage 'We don't know what we don't know' applies to CM. Most agencies have little or no experience and will find that their original plan will require multiple changes and modifications once put into effect. Experience will determine what works and what does not work for a given agency or situation."

Clearly, the CM plan subsequently will change throughout the system's life cycle. For this reason the CM plan is subject to change control and should be treated as any other component of the TMS.

Don't Start Too Big

A common mistake of individuals just getting involved in CM is to attempt to develop an overly complex, comprehensive CM plan, which addresses every possible situation in a system changing through time. Experienced CM professionals note that it is best to start out small and address the essentials. Often, many of the possible scenarios that an agency labors to address in a CM plan will never actually occur.



Implementation Guidance Summary

- A CM program *requires* a CM plan.
- The development of a CM plan must include the active involvement of TMS agency staff.
- Use the following document to guide plan development: CM Plans: The Beginning of your CM Solution (Bounds and Dart, 2001) -- *http://www.sei.cmu.edu/legacy/scm/abstracts/abscm_plans.html*
- Use a standard to guide development. Recommended: the IEEE Standard for Software Configuration Management Plans (IEEE Std 828-1990).
- Put the majority of the effort into crafting CM procedures that work for the agency and TMS.
- Start small – be sure to include essential elements and do not seek to address every possible system change scenario.
- Put the CM plan under CM control.

BEST TRANSPORTATION PRACTICES

Before attempting to plan and manage a CM system, consider what other transportation professionals have done and what practices have proven effective. This section describes the experiences of a number of agencies that have developed and use formal CM plans.

CM Plan Development

Although a handful of agencies use CM without having a formal CM plan, DOTs that have an extensive TMS have seen a need to implement formal documents. This section describes how three DOTs developed their plans, including the resources the agencies used and methodology employed.

Georgia NaviGAtor

The Georgia NaviGAtor program developed its first formal CM plan in 1999. From the beginning, NaviGAtor's CM plan was developed with the help of an outside consultant with constant overview from GDOT personnel, particularly the CM manager. The actual plan took the consultant approximately 9 months to develop, and GDOT spent approximately 50 hours to review and approve it. The consultant who was originally hired to develop the plan had a great deal of personal experience with CM, although not in the TMS environment. In order to compensate for this lack of exposure, the consultant spent a good deal of time talking with GDOT personnel and getting a feel for the environment. The consultant also consulted a few CM books to aid his understanding.

Richmond, VA Smart Traffic Center

The Richmond Smart Traffic Center finished Version 01 of their CM plan at the end of 2001. When the proposal for construction of the STC was originally sent to the Virginia DOT, it provided for a minimal CM system, which included a standard query language (SQL) accessible database containing all inventory information. With this beginning the STC hired two outside consultants from different firms, who then developed the plan and currently serve on its configuration control board. One consultant was with the firm that developed the STC software. The other was an on-call technology support consultant to VDOT. Both were involved to ensure an objective, outside party involvement. The consultants estimated that they spent between five and six weeks working full time to develop the plan. Like the NaviGAtor consultant, the consultants' methodology was derived from personal experience with CM, and they did not use any standards or outside resources. VDOT employees spent less than 10 hours supervising plan development. VDOT employees did use standards and examined projects from other DOT's to assist them with plan revision.

Maryland CHART II System

The Maryland DOT finished development of its first CM plan, which manages only software, in July of 1999. Like the Richmond STC and the NaviGAtor program, the Maryland CHART II System's CM plan was developed by outside consultants, who also developed the DOT's CM software system. According to the consultant, the plan took two weeks to develop working full time. The plan likely would have taken more time to develop if the contractor had not used a standard CM plan that simply required customization to fit the CHART II System's needs.

Example TMS CM Plan Content

Excerpts from the CM plan of the Southern California Priority Corridor illustrate the principles and concepts discussed in this section. This document was originally published on December 5, 2000. Reviews of other TMS CM plans are provided in appendix C.

Reviews and detailed descriptions of TMS CM plans can be found in appendix C.

The following subsections illustrate content of the CM plan of the Southern California Priority Corridor.

CM Program Goals

The document clearly defines the goals of the CM program.

The Goals of Corridor-Wide Configuration Management for the Southern California Priority Corridor are to:

- Ensure sustainability of Southern California Priority Corridor.
- Reduce redundancy and increase the synergy across the current and future corridor projects.
- Provide consistency across the Priority Corridor in areas of Advanced Traveler Information Systems (ATIS), Advanced Traffic/Transportation Management Systems (ATMS) and Commercial Vehicle Operations (CVO) to ensure seamless operations.
- Maximize the Priority Corridor investments for current and future projects while balancing these goals with the autonomy of individual agencies to meet the needs to their Stakeholders.
- Ensure the stability and smooth evolution of the Corridor-Wide System of Systems over time.
- Provide a "Blue Print" and resource for new and existing projects to join the Priority Corridor Network.

Configuration Item Identification

A structure is established for identification of all configuration items as seen in the figure 4.1.

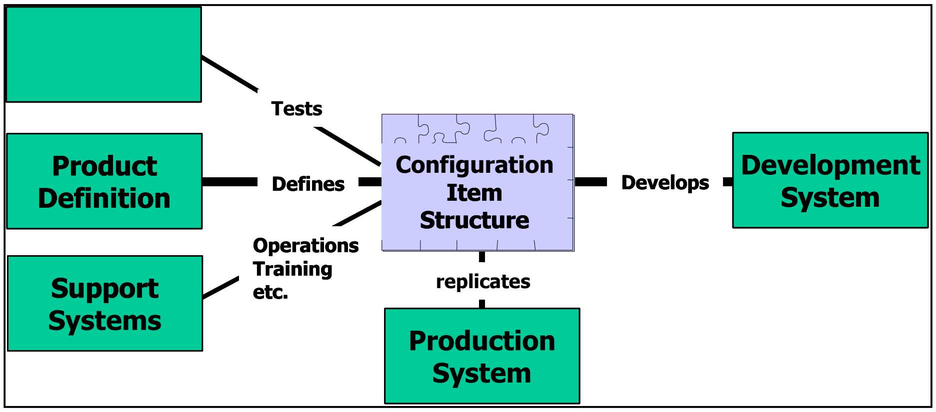


Figure 4.1 Southern California Priority Corridor Identification Structure

Change Control Process

The change control process and procedures are fully documented in the plan. They are summarized in figure 4.2.

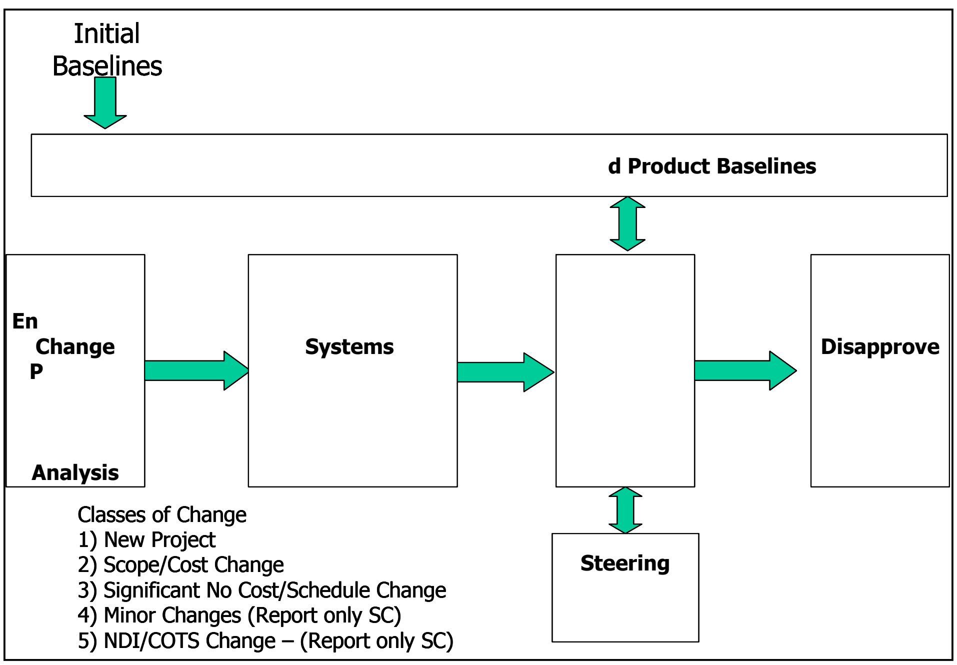


Figure 4.2 Southern California Priority Corridor Change Control Process

CM Program Organizational Structure

The plan clearly lays out the organizational structure required to implement the program. This structure is described graphically in figure 4.3.

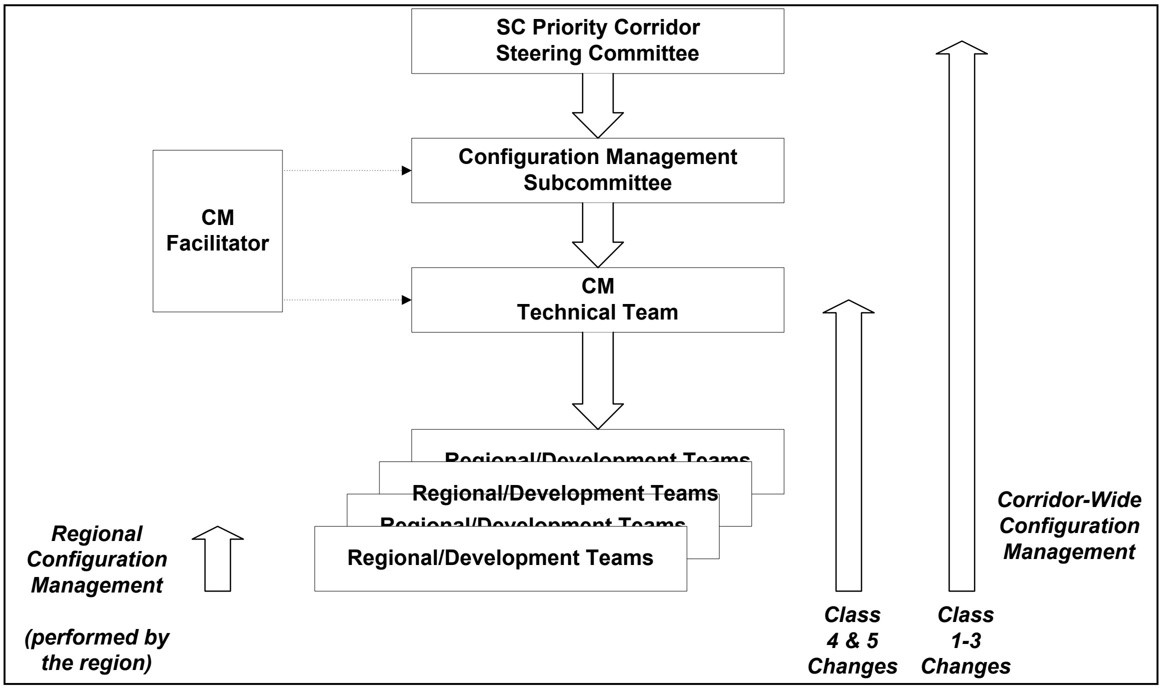
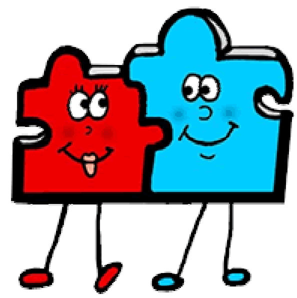


Figure 4.3 Southern California Priority Corridor CM Program Organization

CHAPTER 5 - Configuration Management Baselines

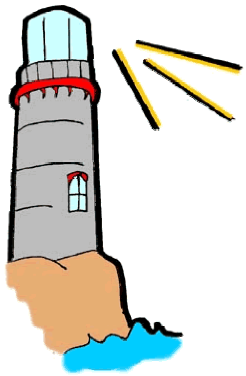


The previous chapters have detailed the key elements of the configuration management process, including the planning element and core processes. This chapter examines the fundamental concept of a system baseline in depth. The concept of baseline is central in configuration management. In order to effectively implement a configuration management program in a transportation management system, one must fully understand baselines.

The concept of a baseline is not new or complex. In general a baseline is a well-defined, well-documented reference that serves as the foundation for other activities. For configuration management a baseline is a stable, well-documented, and thoroughly tested version of the transportation management system at some point in its life cycle. For this reason all configuration management activities should ensure that all changes to a baseline are carefully considered and documented so that future baselines are solid.

This chapter defines and describes the concept of a system baseline, provides guidance for transportation management system applications, and gives examples of effective baselines currently used in transportation management.

IMPLEMENTATION GUIDANCE



Why establish baselines?

Careful attention to establishing formal baselines ensures long-term system availability and supports efficient future system maintenance, integration, and upgrades.

Types of Baselines

Transportation management systems do not have simply a single baseline. In fact, during the life cycle of the system, multiple baselines will be established and maintained. Figure 5.1 provides example system baselines for different points of a typical system life cycle. Figure 5.1 is nearly identical to figure 7.2, which is used to describe the system life cycle in chapter 7. The only difference is that letters have been superimposed on the "control gates" of the life cycle to indicate the appropriate baseline at these gates. The letters correspond to the baselines and descriptions that are presented in table 5.1.

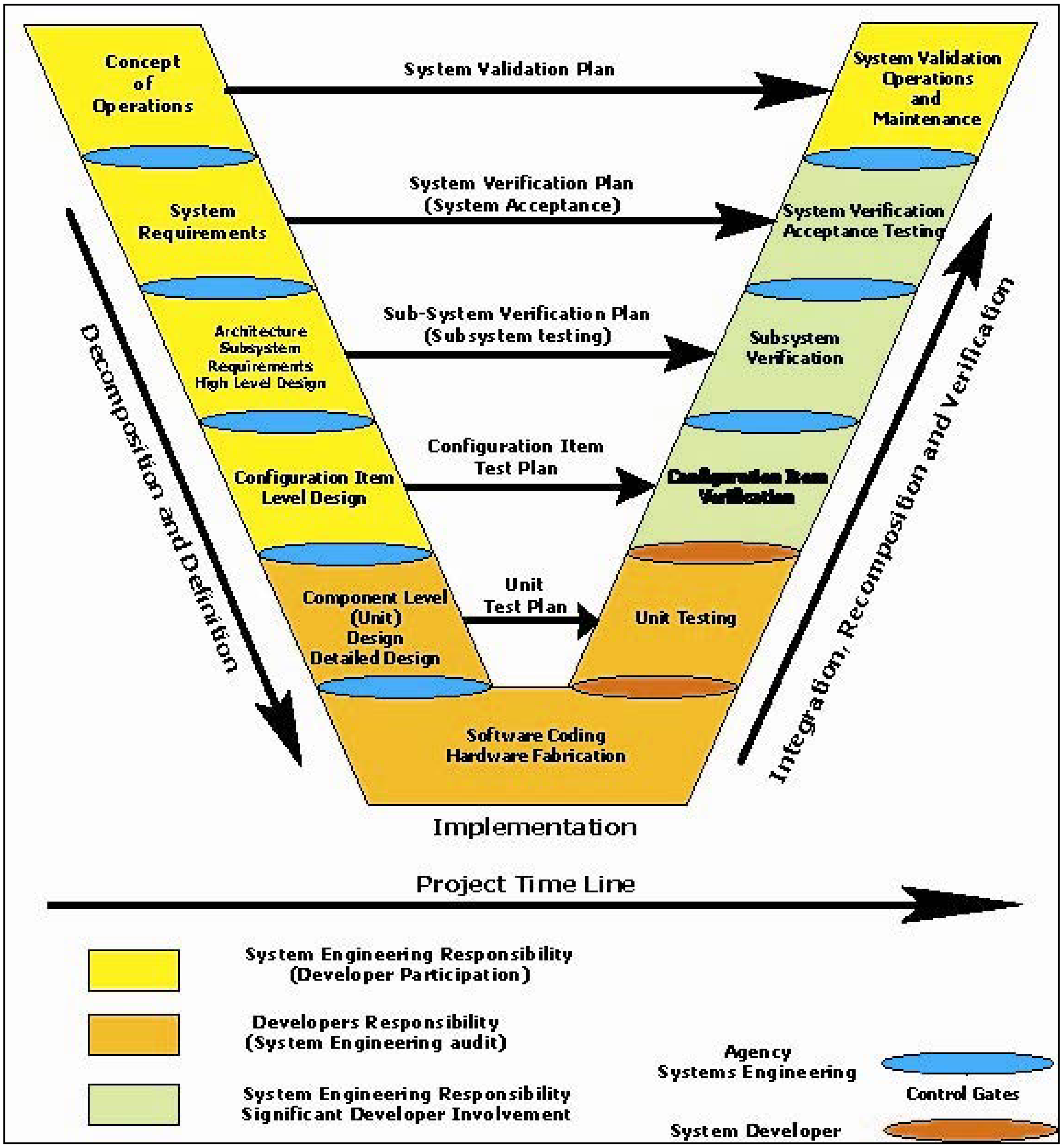


Figure 5.1 Baselines in the System Life Cycle (Control gate letters refer to table 5.1)

Baselines in the System Life Cycle	
A	*Concept of Operations Baseline* – This baseline is established at the conclusion of the system conception stage. In most cases, this baseline may be considered the formal concept of operations document developed for the system. Note that the intention of this baseline is to clearly establish the basic requirements that the system will fulfill.
B	*System Baseline* – This baseline may be considered to be the final functional requirements developed for the system. Often, this baseline may be the set of requirements issued as part of a system acquisition solicitation. In addition, as is the case in many acquisitions, these requirements may be changed slightly based on requirements analysis and negotiation that occurs once a contractor is brought on-board. This is an excellent example of a change to a system baseline that should be carefully controlled through the configuration management program. Note that the system baseline is very important to address the real challenge of scope creep in developing transportation management systems. By establishing and maintaining formal system baselines, project team members will not be able to add/delete requirements without the full team (and usually the configuration control board) fully considering the ramifications.
C	*Subsystem Baseline* - This intermediate baseline between the functional baseline and the development baseline falls after the requirements are completed and preliminary design work has established a mapping of high-level functions to system components.
D	*Development Baseline* – This baseline may be considered to be the detailed design document completed before system development begins. Once system development begins, there will be significant pressure to change system design due to a myriad of reasons (desired new functionality, changes in technology, impediments to development, etc.). It is essential to carefully control these changes to design to maintain the integrity of the system.
E	*Product Baseline* – This baseline essentially documents the “as-built” design that reflects the completed system. The product baseline is the result of the series of changes that have been made to the original developmental baseline during the system development process. Ideally, if the developmental baseline is under configuration control, the product baseline will simply be the evolution of the developmental baseline through the various system acceptance and verification tests, as governed by the configuration control board.
F	*Operational Baseline* – Given the constant pressure for change, transportation management systems are truly “living” systems. In other words, the product baseline will change with time to adapt to the necessary changes. During system operations, it is essential to maintain the operational baseline to reflect changes that have been approved through the configuration management process and implemented.

Table 5.1 – Baselines in the System Life Cycle

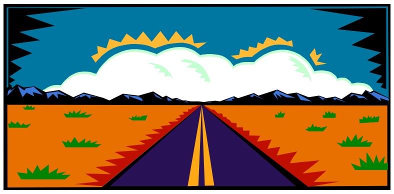
Elements of a Baseline

As noted in table 5.1, all system baselines are not the same. Some baselines purely involve documentation, while others include software, hardware, and so forth. Typical baseline elements are:

Documentation – This is an element of each and every baseline. In some cases, such as the functional baseline, documentation is the entire baseline. In other cases, documentation supplements other elements.

Configuration items – Particularly in the case of software, configuration items themselves should make up portions of the product and operational baseline. For example, the source code for the product baseline should be kept in conjunction with the documentation.

Change documentation – All documentation resulting from the configuration management change control process should be maintained as part of the appropriate baselines, which allows for traceability in the change management process.



Implementation Guidance Summary

BEST TRANSPORTATION PRACTICES

This section describes the experiences of three transportation agencies that use baselines in the configuration management of their transportation management systems.

Georgia NaviGAtor

The Georgia NaviGAtor CM manual states, "The baseline configuration is established at a point in time when GDOT initiates formal control over documentation, drawings, and/or software." Of the agencies that were surveyed for this report, GDOT is the only agency whose plan details the time when a baseline is to be established. After a set of plans has been given to the DOT for a certain project and reviewed to see that all requirements have been met, the agency can baseline that set of plans. From that point on, any changes made during construction should be subject to the change control process. Although the CM manager for the NaviGAtor program expressed some disappointment because it is somewhat difficult to ensure that contractors comply, auditing can help to verify and reinforce compliance to procedures. The CM manager for Georgia also stated that baselining is, by far, the agency's most expensive activity, costing over $500,000 thus far.

Maryland CHART II System

The CHART II CM plan lists five major baselines that are to be included as part of the system life cycle. Under this system, which treats baselines at a project level rather than at an individual item level, the baselines consist of all relevant configuration items (documents, software, and other items). Similar to the multiple, concurrent baselines illustrated in figure 5.1, the CHART II plan stipulates that at any point the project may be supporting multiple baselines. As an example, the plan says that Release 1/Build 2 may be operational while Release 1/Build 3 may be in development and Release 2/Build 1 may be in design. As is standard with baselining procedures, CHART II baselines are modified using the change control process. The CHART II project baselines are shown in figure 5.2.

Description	When Established	Content	Controlling Authority
Requirements Baseline (for each Release/Build)			
Business processes and threads; requirements for technology insertion or replacement; and data, facility, and security requirements. Defined relationships among system components and external interfaces.	At a System Requirements Review (SRR) held at the end of the Business Area Architecture (BAA) phase	➢ CHART II requirements ➢ BAA Report ➢ Interface Control Documents	CHART II CCB
Design Baseline (for each Release/Build)			
Requirements translated into high-level design products, including database design. Each element is traceable to one or more requirements and each requirement to one or more design element.	At a Design Review (DR) held at the end of the design phase	➢ Design Documents ➢ Accelerated Business Process Design (XBD) Report ➢ Logical models for each Catalyst domain ➢ Business Area Plan	CHART II CCB
Development Baseline (for each Release/Build)			
Design products translated into custom software, COTS products, and hardware components integrated and tested in the development environment.	At beginning of integration testing	➢ Developed software system/integration hardware configurations ➢ Unit and Integration Test Plans ➢ I.V. & V. code review results	Development Organization
Independent Test Baseline (for each Release/Build)			
Configured independent test environments.	At system test and acceptance test readiness reviews (STRR, ATRR) held before installation at each test configuration	For each site: ➢ Unit and Integration Test Results ➢ Developed software system/test hardware configurations ➢ Factory and Acceptance Test Plans and Procedures ➢ Installation Procedures	CHART II PRB
Operational Baseline (for each Release/Build)			
Operational system at each site.	At transition readiness review (TRR) held before installation at each operational site	For each site: ➢ Operational software/hardware system ➢ Transition Plan ➢ Installation Procedures ➢ Operational documentation ➢ Independent test results	CHART II CCB

Figure 5.2 CHART II Project Baselines

* Maryland CHART II Project Configuration Management Plan - 10/2000 (p. 3-3)

Southern California Priority Corridor

The Southern California Priority Corridor lists three categories of baselines in its CM plan. They are:

- Functional Baseline – Baselines on the system-of-systems level and corridor-wide configuration items
- Allocated Baseline – Baselines on the system level and project level configuration items
- Product Baseline – Baselines that include the detailed design of developed software, hardware, or firmware
  - SCPC CM Plan (p. 5-4)

Figure 5.3 illustrates the allocation of baseline to life cycle stage.

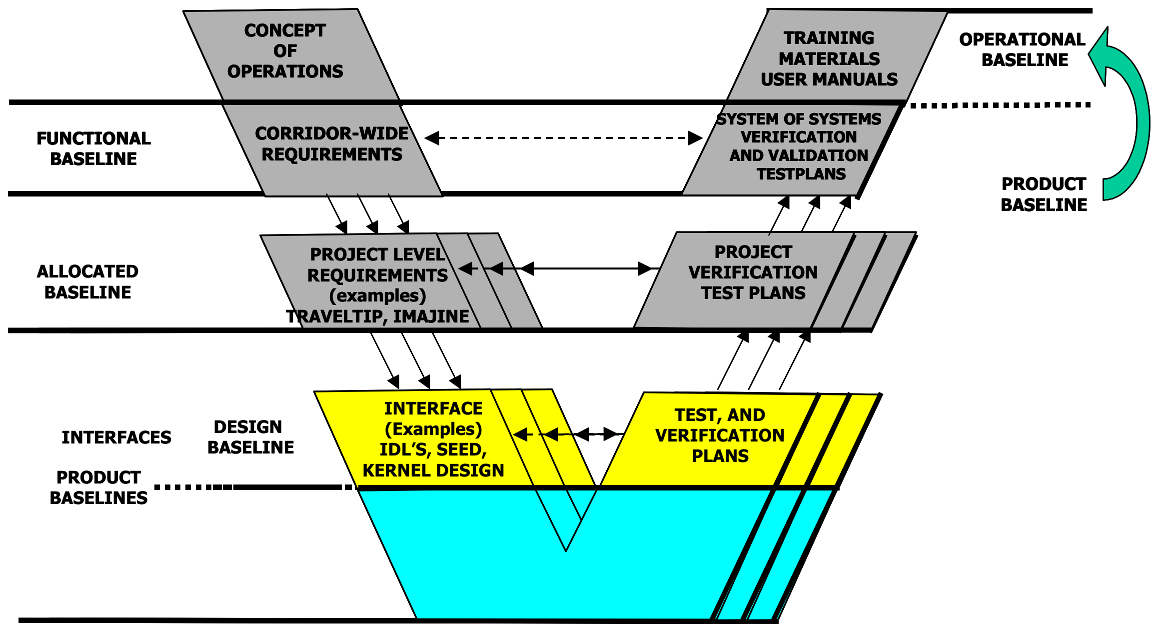


Figure 5.3 SCPC Baselines in Context of "Vee" Systems Engineering Model

* Southern California Priority Corridor Configuration Management Plan, December, 2000 (p. 5-5)

CHAPTER 6 -
Configuration Management Program Making it Work in Your Agency

The previous chapters have provided a solid foundation in the CM process, with special emphasis on key areas such as planning and baselines. Section III focuses on implementing the CM process into a comprehensive program for a TMS. This chapter provides specific guidance and examples to help transportation professionals begin to implement or improve a CM program to manage change and maintain the integrity of a TMS.

Topics to be covered include:

- Establishing a CM program.
- Organizing for CM.
- Personnel.
- Budgeting considerations

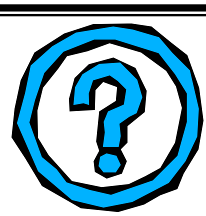
ESTABLISHING A CM PROGRAM

One of the most frequent statements of individuals considering CM is "I don't know where to begin." Although this guidance document does go into considerable depth concerning the various aspects and components of CM, the fact remains that it is possible—and advisable—to start small. Starting small will help an organization make better decisions as the CM program starts—even when the system is large. This section provides guidance on establishing a CM program and presents the experiences of two agencies.

IMPLEMENTATION GUIDANCE

As with any new initiative, a champion must spearhead the establishment of a CM program. Sometimes, the champion faces a difficult battle, particularly due to cultural resistance within the agency. CM often is viewed as an expensive bureaucratic process with benefits that are hard to quantify. For this reason, the champion must educate decision makers and system staff on what CM is, and isn't, as well as describe the benefits of CM in a tangible manner. The champion also must secure funds or staff time to use in creating a CM plan for the program.

Once initial buy-in has been established, the next step is to create a CM plan. Depending on the complexity of the system, the plan may be developed in-house or by a consultant. Regardless of the developer, the agency must be actively involved in the entire plan development process.

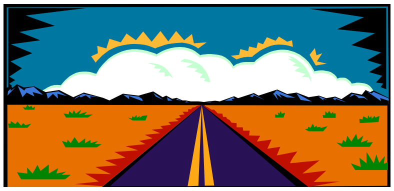


For more information on configuration management planning, see chapter 4.

Plan developers must think beyond the issues most directly related to CM: thoroughly understanding the management structure of the agency is also vital. As one transportation professional with extensive CM experience noted, "How resources are allocated to projects and ongoing operations and maintenance efforts within an agency should influence how the plan is developed. If resources are not under the control of the TMC system managers, the methodologies for accomplishing change control and other items may be different."

Once the plan is developed, the blueprint is in place to drive the program. The champion must make it clear to decision makers that the creation of the plan is but the first step in the program. Committing to CM means a long-term staff, budget, and procedural commitment.

An ideal way to implement CM is at the onset of the development of a new system. In this case the CM champion should use CM to manage initial system requirements and require development contractors to use CM throughout their activities. Early inclusion of CM allows for a natural progression of the CM program into the operations and maintenance stages of the system life cycle. It is not too late, however, to implement CM if a TMS already exists. The guidance provided in this section applies equally well to initiating CM for an established system.



Implementation Guidance Summary

- A CM champion is needed.
- Ideally, incorporate CM during the requirements and development phases.
- CM program begins with educating decision makers and staff on the realities of CM and the benefits of a CM program.
- Be sure all involved understand that CM is an ongoing program, not a short-term project.

BEST TRANSPORTATION PRACTICES

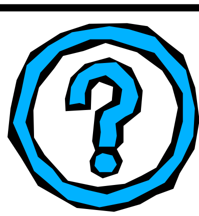
The experiences of GDOT and Maryland State Highway Administration in establishing CM programs are described below.

Georgia NaviGAtor

The GDOT NaviGAtor CM plan and program were initiated in 1998 based on the desire to manage change in an effective, efficient manner. One particular member of the engineering staff took on the role of CM champion and promoted its adoption for the NaviGAtor system. There was very little institutional resistance to adopting CM because the benefits were perceived to be worth the resources required and because the risk of adverse effects of changing the system in an unregulated manner was determined to be too high.

Because few people at GDOT had any experience with CM, the agency found it necessary to hire a consultant. The initial consultant had significant CM experience, but knew very little about ITS. This consultant was replaced by one that was both familiar with ITS and a CM expert. The knowledge that he possessed was cited as invaluable to the establishment and maintenance of the NaviGAtor CM manual. The NaviGAtor CM manager noted, however, that even an expert will not produce an ideal document the first time. Agencies must be prepared to make revisions to the CM program and CM plan based on lessons learned during their use. There have been five major versions of the NaviGAtor CM manual, with both major and minor revisions occurring in between.

One of the initial challenges facing the NaviGAtor team during establishment of the CM program was baselining its existing system. Many meetings and personnel-hours were devoted to figuring out precisely which items and subsystems would fall under baselining. The actual collection of information, such as documentation, code, hardware, and so forth, required significant resources of personnel-hours and money as well.



Chapter 5 is dedicated to the topic of baselines in configuration management.

Maryland CHART II System

The CM program for the CHART II system was initiated by the current system administrator based on his CM experience gained in software development. A primary reason for initiating the CM program was that the system administrator held the belief that CM is just “the right way to do it.” New executive leadership within the organization and a desire to make the system more capable of undergoing change smoothly meant that the idea of CM for CHART II encountered little resistance. Once establishment of a CM program had been approved, consultants were hired to develop the CM plan, with significant oversight and involvement of the system administrator.

ORGANIZING FOR CM

The success of CM is solely dependent on how well an agency organizes itself to institute the required polices and processes. This section addresses the issue of organizing staff to successfully carry out a CM program. Three primary subjects are covered:

1. CM Administration.
2. CM Manager.
3. Configuration Control Board (CCB).

CM ADMINISTRATION

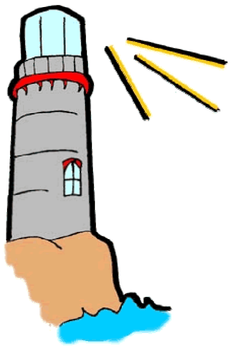
This subsection describes administrative structures that effectively support CM in transportation agencies. Most agencies have several personnel with various responsibilities in the CM program. A typical agency's program is overseen by the CM manager and is staffed by a team of technical and administrative personnel. In most cases outside consultants act as CM facilitators or advisors to assist with the operation of the CM program.

CM administration is crucial to the proper functioning of the CM program. Whether CM managers, CM facilitators or the CCB, all play important roles in the decision-making process. The CM administration is responsible for such considerations as:

- Assessing proposed system changes.
- Determining the fate of proposed changes.
- Ensuring all staff is familiar with the CM program.
- Providing necessary resources for the CM program.
- Training relevant staff in the CM program.
- Modifying the CM program based on assessed need.
- Controlling changes to the CM plan.

Because of these important responsibilities, managers must exercise care in choosing personnel to be part of the CM administrative bodies. As discussed in the "Implementation Guidance" section, personnel should come from a wide variety of backgrounds with skills in numerous areas.

IMPLEMENTATION GUIDANCE

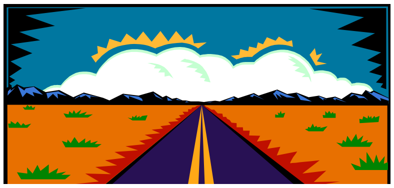


Effective CM administration starts at the top. The TMS facility/system manager *must* play an active role in the CM program. In most cases this individual serves on the CCB and, in some cases, serves as the CM manager. In *all* cases, the TMS facility/system manager must fully support the program and become involved on critical change decisions.

Depending on the size of the system and complexity of the CM program, the CM administration may be comprised of a large or small group of individuals. Regardless of the administration's size, the roles of each individual within the CM administration must be well understood. The CM plan should specify the responsibilities of each person involved in the CM decision-making process. The Georgia NaviGAtor team member responsibility chart is an excellent example and illustrated in figure 6.1 in the "Best Transportation Practices" subsection.

Another important factor to consider when establishing the CM administrative structure is that decision makers should come from a variety of specialties and areas of focus. In order for the CM program to be as effective as possible, it is ideal to include personnel from across the spectrum of departments, such as planning, management, technical/design, operations and maintenance, and financial. Doing so ensures that no areas are overlooked during the application of the CM program and reduces the chances of the CM activities of one group overlapping or conflicting with those of another. Roles essential to CM administration are:

- CM manager.
- CM facilitator or advisor.
- Technical experts.
- Respective project managers.
- Document specialists.



Implementation Guidance Summary

- The TMS system/facility manager must play an active role in CM administration.
- The roles of all personnel must be clearly defined and the relationships among them must be understood.
- The CM plan should clearly state specific tasks and requirements of all personnel involved in CM administration.
- The personnel involved in the administration of a CM program must have a variety of focus areas including: management, planning, financial, and technical.

BEST TRANSPORTATION PRACTICES

Georgia NaviGAtor

The Georgia NaviGAtor CM plan describes in detail the personnel responsible for making decisions related to its CM program. According to the plan, personnel working within the CM program has two responsibilities: 1) to act as members of the configuration control board and 2) to act as general administrators on routine issues that may arise, but do not require CCB action. The administrative issues include items such as budgeting, planning, and the recommendations of new procedures. Figure 6.1 specifies the duties of key administrative personnel:

CM Manager	CCB Chairperson
	Plans and implements overall CM program
	Prepares and provides CM status reports
	Provides CM training
	Identifies CM resources
	Directs overall CM activities
	Maintains and develops CM procedures
	Plans and implements formal CM audits
	Identifies CM baseline requirements
	Attends formal project reviews
Program Manager	CCB permanent member
	Provides appropriate schedule, budget, and resources
	Helps in planning overall CM program
	Oversees overall project reviews
	Identifies CM report requirements
	Helps CM manager determine CM training for GDOT employees
	Helps CM manager determine CM baseline requirements
CM Advisor	CCB advisor

	Recommends training requirements
	Recommends new CM procedures or changes to existing ones
	Helps CM manager monitor overall CM activities
Software Manager	CCB permanent member
Hardware Manager	Verifies that personnel are following CM procedures
Systems Integrator	Assists in CM audits
Operations Manager	Evaluates and manages COTS software (if applicable)
Design Manager	Provides Q/A evaluation and assurance of changes to baseline items
	Initiates and/or attends formal project reviews
	Help determine training requirements by providing expertise in each functional
	area
	Attend CCB as administrative help to CM manager
Document Manager	Maintains documentation repository
	Assists in CM audits
	Documentation manager
	Evaluates and manages COTS software (if applicable)

Figure 6.1 Georgia NaviGAtor CM Team

* GDOT NaviGAtor Configuration Management (CM) Manual NAV01-004 – Rev. 5.0: 12/19/01 (p. 2-1)

<u>Southern California Priority Corridor</u>

Because the Southern California Priority Corridor involves multiple regions and jurisdictions working together, the organization for CM decision-making is different than typical CM programs. The project director in the Priority Corridor's Project Office leads the CM program. Several tasks and positions have been specified to be part of the CM program administration. Figure 6.2 describes these roles:

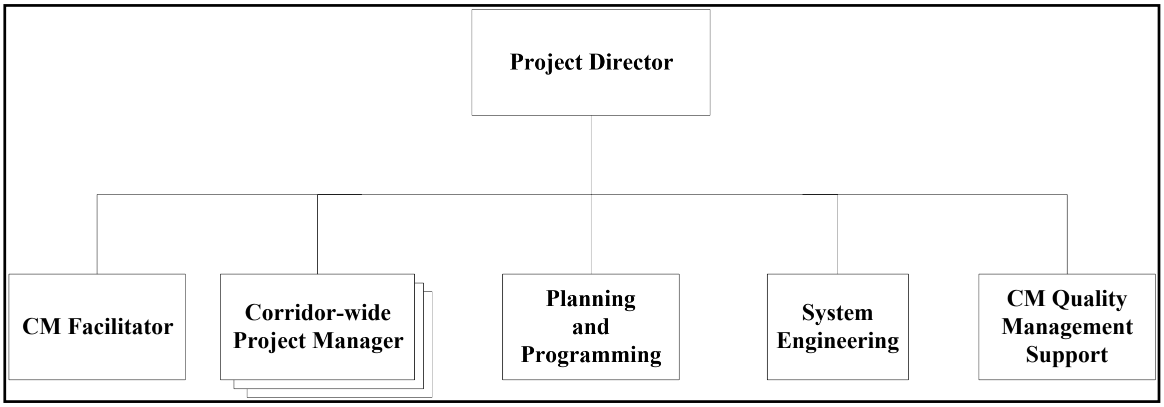


Figure 6.2 Project Office Organization

* Southern California Priority Corridor Configuration Management Plan, December, 2000 (p. 3-2)

Staffing has been devoted to each of these areas to help ensure that the system is properly managed.

Maryland CHART II System

The CHART II plan describes the CM Office as the central, organizing body for the system's CM activities. The CMO assures that the standards and procedures specified in the plan are adhered to, helps establish and maintain baselines approved by the CCB, and aids in problem resolution and change management. The CMO also must create configuration status reports and is responsible for the baseline reviews and audits. The CMO administers the software library and a library of documentation for all project deliverables.

The plan specifies two major boards central to the CM program. The first, the CCB, is discussed in chapter 3. The other board is the CHART II Level B Problem Review Board. Level B changes are those done to development baseline items or other items specified by the Project Manager. This board meets when necessary to address all Level B problems. The CMO is responsible for the organization of the meetings and the tracking of all Level B problems. The members of this board include:

- Task manager (chairperson).
- The CM Office.
- Quality assurance representative.
- System test manager.
- Development manager.
- Database designer.

Richmond, VA Smart Traffic Center

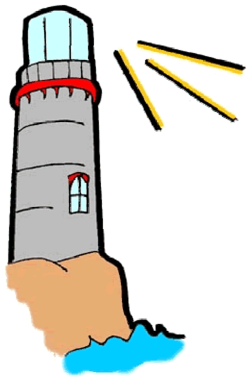
The Richmond Smart Traffic Center CM plan calls for two major boards to help administer the CM program: the CCB and the Issue Mediation Board. The CCB is discussed in chapter 3. Each of the boards is comprised of personnel from VDOT and from the prime and subcontractors. Personnel from VDOT chair both boards.

The IMB exists to resolve problems regarding software changes that cannot be solved by the CCB. It is made up of three persons, one chairperson from VDOT and one person from each of the contractors working for the Smart Traffic Center. Project level management personnel staff the IMB

CM MANAGER

This section introduces the essential position of CM manager. The primary responsibilities of the CM manager are to direct the CM program, chair the CCB, and oversee the execution of all CCB decisions.

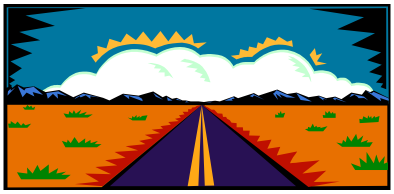
IMPLEMENTATION GUIDANCE



An active CM manager is essential to an effective CM program. Having one individual who is ultimately responsible for the execution of the CM plan and policies centralizes the program and is preferable to having to rely on the CCB for program delivery. In essence, the CM manager may be considered the executive branch of government, while the CCB or other boards could be considered the legislative branch. The manager is responsible for verifying that all new policies and procedures determined by the boards are followed as closely as possible. When it is not possible to follow these procedures due to technical or other reasons, the manager is called on to determine a solution that will work within the CM program.

In large-scale CM programs, it usually is necessary to devote an entire position to the role of CM manager. In smaller programs the CM manager often has other responsibilities. (For example, in many cases the CM manager also is the TMS system/facility manager). The CM manager does not need to be a highly technical individual. Detailed technical review can, and in most cases should, be carried out by engineering staff. A successful CM manager is an individual with an appreciation for technical considerations and who has a sound understanding of personnel, operations, and budgeting issues within the TMS.

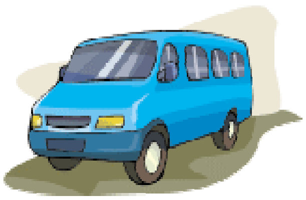
The CM manager should *not* be allocated to a consultant or contractor member of the CM team. Given that the agency is the owner and ultimately responsible for the TMS, the CM manager must be an agency staff member. The CM manager may be assisted by consultants, but final decisions and responsibility for TMS change control must rest with the CM manager.



Implementation Guidance Summary

- A CM manager, employed by the transportation agency, must be formally established to lead the CM program.
- The CM manager will be the chair of the CCB.
- The CM manager should be an individual with an appreciation for technical considerations and who has a sound understanding of personnel, operations, and budgeting issues within the TMS.

BEST TRANSPORTATION PRACTICES



Georgia NaviGAtor

In the Georgia NaviGAtor CM plan, the CM manager is the overall director of CM activities. The plan describes the position's particular duties in detail. These duties are described in general in figure 6.1 in the previous subsection. The CM manager is responsible for leading all CCB meetings and presenting all System Change Requests to the CCB. If there is disagreement over what should be done regarding a certain SCR, then the CM manager will lead the discussion until a consensus is reached. If special circumstances need to be discussed at one of the meetings, the manager may select additional personnel to attend the meetings.

In summary, the primary responsibilities of the CM manager are, as stated in the NaviGAtor CM manual:

1. Scheduling CCB meetings in conjunction with the program manager.
2. Updating and issuing status reports.
3. Assigning change assessment resolution team leader if required.
4. Tracking the progress of assessment team to assure timely progress.
5. Managing data repositories.
6. Managing and revising CCB related CM procedures.
7. Assuring SCR and related information is complete and accurate.
8. Requesting additional personnel to attend CCB meetings if needed.
9. Assuring operational disciplines of the CCB CM process are being followed.

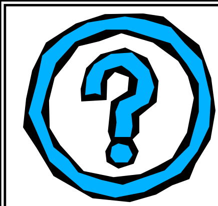
* GDOT NaviGAtor Configuration Management (CM) Manual NAV01-004 – Rev. 5.0: 12/19/01(p. 4-3)

Maryland CHART II System

The Maryland CHART II CM plan does not specifically mention a CM manager, but calls for a project manager to be responsible for promoting the CM activities and for ensuring that the goals of the CM program are met. The project manager is the chair of the CCB and has final approval on CCB issues. In addition, the plan describes the duties of the task manager. The task manager is a contractor-provided manager that ensures that the CM program is applied during projects and that all components of the plan are carried out as specified.

CONFIGURATION CONTROL BOARD (CCB)

The CCB is one of the most important aspects of a CM program and is responsible for all of the major change decisions that will affect the system. The CCB is chaired by the CM manager and is usually aided by a CM facilitator or CM advisor (often consultants with CM expertise—see chapter 9). The board meets on a regular basis, typically monthly or bimonthly to evaluate all proposed changes to the system and to determine a course of action.

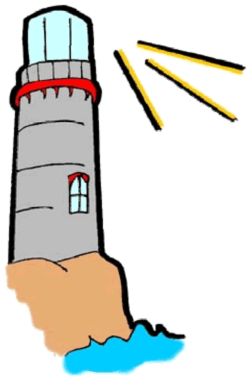


The section on change control in chapter 3 includes detailed information about CCBs

PERSONNEL

The fact that the effectiveness of a CM program depends on the people involved cannot be stated too often. The purpose of this section is to describe the attributes an agency should look for when selecting or recruiting members for a CM team.

IMPLEMENTATION GUIDANCE



The good news concerning personnel involved in a CM program is that the program generally does not require a host of highly educated technical geniuses. In fact, as seen in chapter 3, CM is largely concerned with a commitment to using a common sense and rigorous approach to documentation. The following knowledge, skills, and abilities (KSAs) are desirable in any staff member associated with the CM program.

- Detail oriented.
- Commitment to teamwork.
- Excellent communication skills (verbal and written).
- Organized.
- Knowledge of basic systems engineering process.
- Knowledge of CM basics.
- Knowledge of project management basics.

Beyond these basic KSAs, personnel recommendations are presented for the CM manager position, CM facilitator, and the CCB.

CM Manager

The CM manager should have a solid background in TMSs and the functioning of a transportation agency. The CM manager preferably will have prior experience in CM or else should receive significant training before initiation of the CM program. Because the CM manager runs the CM program, he or she must possess overarching knowledge of the entire program and the concepts involved with CM in general. The CM manager spends more time than any other staff member devoted to the CM program (ranging from 10 to 40 hours per week depending on its scope).

CM Facilitator

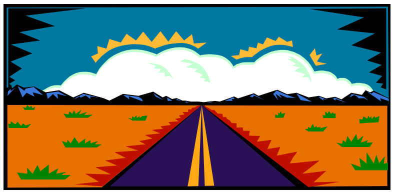
The CM facilitator is typically a consultant or contractor with prior CM expertise. The facilitator must have detailed CM experience to be of value to the TMSs CM program. The CM facilitator, together with the CM manager, should be responsible for training all other personnel, including the members of the CCB. For this reason, the facilitator should have a strong working knowledge of the tools in which staff will be trained and of the specific procedures and policies that the staff is to follow.

It is strongly suggested that an agency require the CM facilitator be CMII certified. CMII is an approach to CM developed by the Institute of Configuration Management (www.icmhq.com). In order to receive CMII Certification, one must complete the following six 2-day courses:

- Configuration Management & the CMII Model.
- Structured Configuration and Process Information.
- Key Elements of Change Management.
- Closed-Loop and Fast Track Change Process.
- CMII Operating Standards and Legal Liabilities.
- CMII Assessment, Implementation and Application.

CCB Members

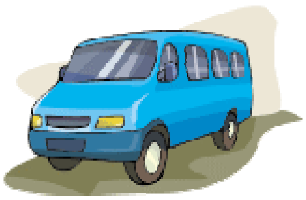
CCB members, other than the CM manager and the CM facilitator, will require significant training in terms of CM policies and the processes involved with CM, such as filling out and evaluating change requests. Board members also require training in the use of the CM tools. Training CCB members typically requires several days, and board members can expect to spend a few hours per week devoted to CCB matters.



Implementation Guidance Summary

- Consider basic KSAs described in this subsection when selecting any staff member to be involved in CM program.
- CM manager must have strong TMS experience. CM experience is preferable, but in-depth training can be used as a substitute.

BEST TRANSPORTATION PRACTICES



Given that CM is still relatively new to transportation agencies, very few CM-specific personnel practices are documented. General information obtained through interviews with transportation professionals is provided in this section.

Administrative Capabilities

Transportation professional agreed that the key to success in CM is strong administrative capabilities. The professionals stated that they generally look for well-organized, strong administrators for CM positions, and then seek to provide them CM-specific training to provide CM knowledge.

Resources to Support More Formal KSA Development

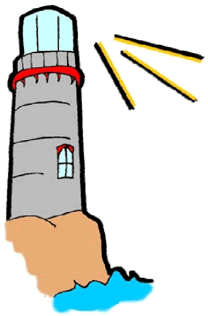
In the event that an agency progresses to a point where formal CM-specific position descriptions are appropriate to develop, it is important to remember that these positions require having a strong domain foundation in transportation management. To support this effort, transportation professionals recommended using the final report of the project TMC Operator Requirements Matrix, currently being completed as part of the TMC Pooled Fund Program. This project has developed full position descriptions for the following transportation management-related positions. Information from these descriptions should be included in a CM position as appropriate.

1. NETWORK SYSTEMS TECHNICIAN
2. TRAFFIC SIGNAL TECHNICIAN I
3. TRAFFIC SIGNAL TECHNICIAN II
4. TRAFFIC COMMUNICATION TECHNICIAN I
5. TRAFFIC COMMUNICATION TECHNICIAN II
6. SENIOR TRAFFIC SIGNAL TECHNICIAN
7. SENIOR INTELLIGENT TRANSPORTATION SYSTEM (ITS) TECHNICIAN
8. TRAFFIC SYSTEMS ENGINEERING SUPERVISOR
9. OPERATOR I

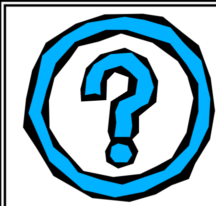
BUDGETING CONSIDERATIONS

Before any CM planning or activity can be started, sufficient resources must be available to complete the task. This section addresses CM program costs, which are broken down into two main categories: initial costs and ongoing costs. Initial costs occur when CM is first being implemented – primarily during the planning phase. An ongoing cost is one required for the day-to-day activities of CM. Examples of ongoing costs include paying personnel for the time spent in CCB meetings and the cost of retaining an outside CM consultant.

IMPLEMENTATION GUIDANCE



CM plan development requires significant resources as an agency begins a CM program. Depending on the complexity of the TMS and scale of the CM program, the cost of plan development may vary greatly. Plan development can involve roughly one month of full-time effort, at a minimum, for a “simple” CM program to one year of full-time effort for a complex program.



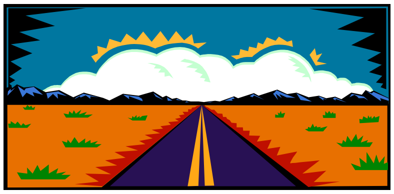
Examples of resources required for CM

Finally, an agency must keep in mind that the costs for CM plan development will include a significant amount of staff time devoted to the effort.

Once the CM plan is complete and an agency begins the CM process, ongoing costs are necessary to support the program. CM experts stated that generally an agency can expect to devote roughly 5 to 8 percent of the initial system cost on CM annually. This cost includes staff, consultant, and associated CM tool expenses.

The CM processes often require additional tools (see chapter 8) to track configuration items through the TMS life cycle. Associated costs include the initial purchase of the tool, ongoing annual license fees (usually10 to15 percent of initial cost), and staff time devoted to using the tool. An additional ongoing cost to keep in mind is the cost of staff training during the system life cycle. Training will be required at different points throughout the life cycle as the system and the CM program are enhanced. The use of new tools, as well as new CM program processes, requires staff training. Available resources for CM training are described in chapter9.

Providing concrete recommendations on budget requirements for a CM program is extremely difficult, particularly given the significant differences in TMS needs and alternatives for CM program “delivery.” The general guidance provided in this chapter is intended to help transportation professionals consider key issues as they embark on the budgeting process. The experiences of transportation agencies, provided in the next section, also can help with this process.



Implementation Guidance Summary

- Expect CM planning to require between 1 – 12 person months of effort.
- Annual costs of a CM program are generally 5 – 8 percent of initial system cost.
- Ongoing CM costs include staff time, consultant support, tool purchase/maintenance fees, and training.

BEST TRANSPORTATION PRACTICES

Georgia NaviGAtor

The costs associated with development of the NaviGAtor CM program were relatively high, which is not surprising given the complexity of its system and CM program. Development of the CM plan took a full-time consultant about a year and required about 50 hours of staff time. The agency also created two positions to facilitate CM: the CM manager and documentation control manager. The CM manager is a G-14 level position with a pay range of $27,000-49,000. The documentation control manager is a G-12 level position with a pay range of $22,000-42,000. The agency also hired an outside consultant to help with its CM activities. The consultant works full time doing NaviGAtor CM work, which includes establishing baselines and conducting training. The cost of the consultant was not made available to the study team, although it was stated that normal consulting fees were a good estimation.

Richmond, VA Smart Travel Center

The Richmond STCs CM costs can be broken down similarly to NaviGAtor's costs. During development the CM plan required staff time of less than 10 hours and took 2 consultants 40 hours each. The CM manager estimates that the agency spends $5,000 per month for in-house personnel CM activities, and $20,000 per month for CM consultants and contractors. Unlike the NaviGAtor program, Richmond does not have any specific outlays for CM tools. The tools are covered in its consultant expenditures.

Maryland CHART II System

The Maryland CHART II System CM program controls software and the related documentation. According to the system administrator, the CM plan took a full-time consultant two weeks to develop. The system administrator spends about four hours monthly on CM, and a CM consultant works full-time. As with Richmond STC the consultant maintains the software and is responsible for providing the CM tools.

CHAPTER 7 - Configuration Management and the System Life Cycle

As a transportation management system progresses through its life cycle, it will be altered in a number of ways to support such areas as improved functionality, regional integration, and so forth. In order for a CM program to effectively address change, CM must be included in each and every stage of the system life cycle, starting with the concept of operations.

Configuration Items

Before examining CM's role in each phase of a system life cycle, it is useful to review the definition of a configuration item and consider the elements that "surround" each item and enable the item to function as intended.

As described in chapter 3, transportation agencies generally consider all software components, communications cable, and hardware involved in their transportation management systems to be configuration items. Figure 7.1 illustrates the relationship of configuration items to the various elements that "enable" these items. In other words, each of the elements takes place during the system's life cycle in order to ensure that the configuration item successfully provides its intended function.

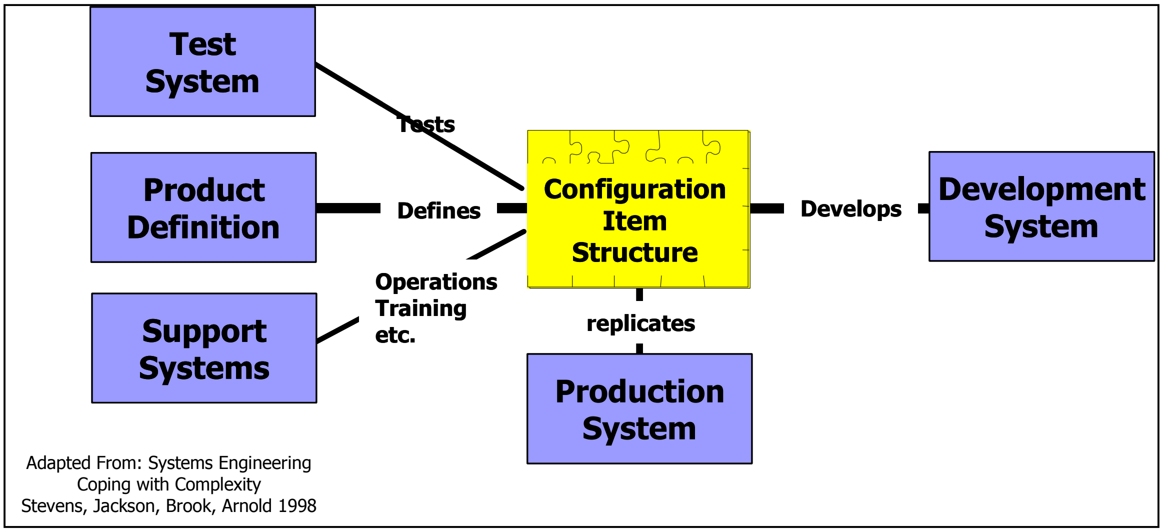


Figure 7.1 Configuration Items and Supporting Elements

In order to better interpret this figure, consider the following activities/resources, which are included in each of the elements:

- *Test System* – test plan, test procedures, test environment, simulators, and test jigs.
- *Product Definition* – requirements, high-level design, detailed design, traceability matrix.
- *Support Systems* – operator manuals, training manuals, maintenance manuals.
- *Production Systems* – production process and environments.
- *Development System* – build environment, procedures, patches.

Each of these elements directly supports configuration items. Consequently, the integrity of the system is reliant upon the elements, which is why the elements must be placed under configuration control. Given that each element takes place during different phases of the system life cycle, the next section will directly address these phases.

System Life Cycle

Figure 7.2 specifically illustrates configuration items and their associated elements in the context of the "Vee" diagram commonly used to describe a generic system life cycle.

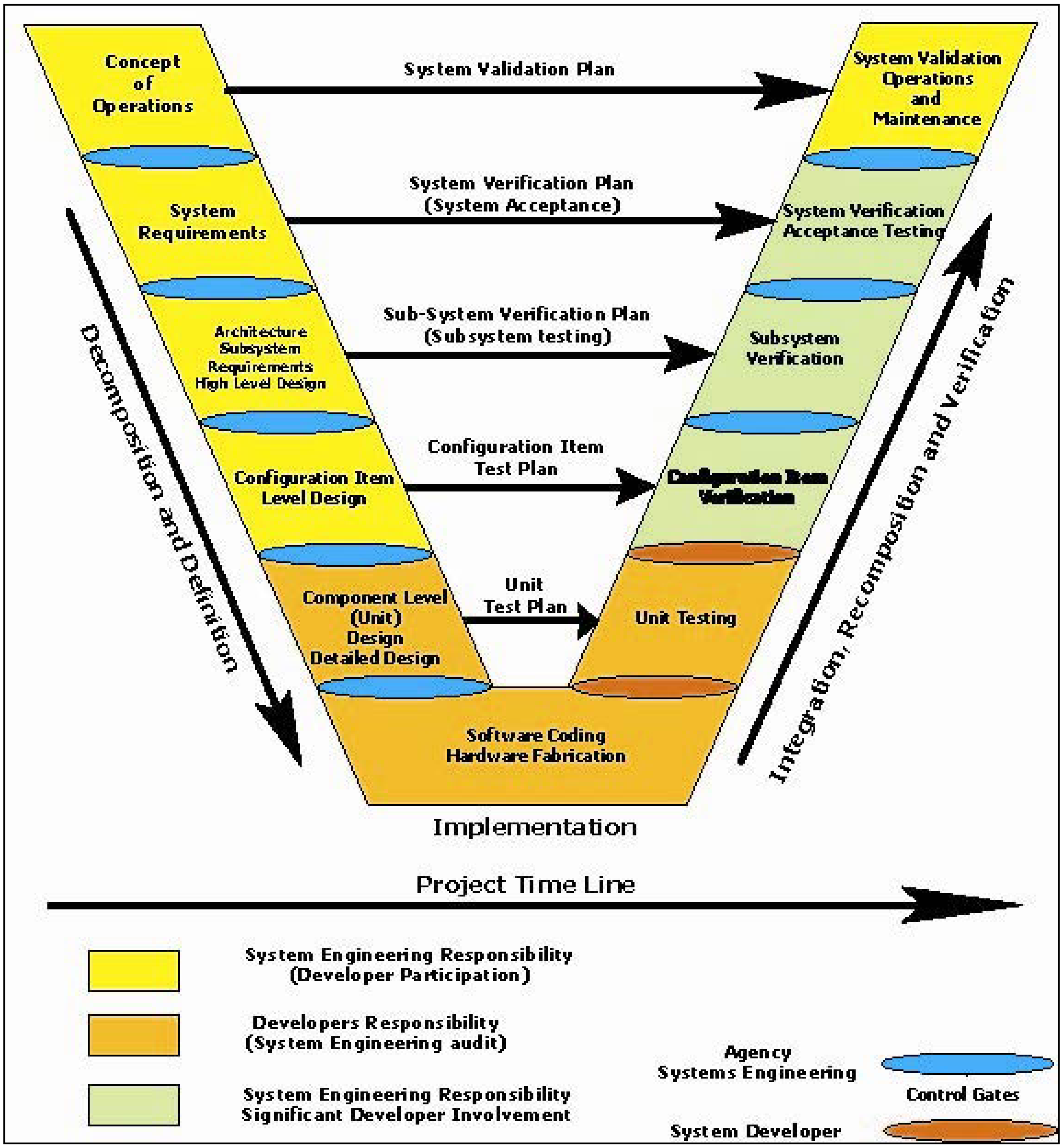


Figure 7.2 The Systems Engineering Life Cycle and Configuration Items

As seen in figure 7.2, the system life cycle begins at the very outset of exploring the concept of operations, and then continues throughout system use and maintenance. Best practices in configuration management are to incorporate CM in each and every stage of the system life cycle. In table 7.1 elements of the configuration management process described in chapter 3 are mapped to stages of the system lifecycle, which are illustrated in figure 7.2.

System Life Cycle Stage	Config. Mgmt. Planning	Config. Identification	Config. Control	Config. Status Accounting	Config. Audits
Concept of Operations	√				
System Requirements		√	√		
High Level Design		√	√	√	
CI Level Design		√	√	√	
Component Level Design		√	√	√	
Implementation		√	√	√	
Unit Testing			√	√	√
CI Verification			√	√	√
Subsystem Verification			√	√	√
System Verification			√	√	√
Operation and Maintenance			√	√	√

Table 7.1 CM and the System Life Cycle

* Adapted and expanded from Gonzalez, "A Guide to Configuration Management for Intelligent Transportation Systems" – April 2002

Traceability Through the Life Cycle

As systems age, personnel come and go, and technology changes. Accurately recalling details of why certain design decisions were made in the past often becomes very difficult to do. This lack of institutional memory, which is unavoidable without a solid configuration management change control system, results in a significant loss of efficiency. Thus, a key benefit of including configuration management throughout the life cycle is to ensure traceability. Although traceability may appear to be a complex systems engineering term, it simply is the concept of documenting how and why the system has arrived in its current state. An important fact to note about the system life cycle diagram of figure 7.2, is that each and every configuration item of a system is traceable to its parent high-level design, requirements, and concept of operations.

Traceability begins at the requirements stage. Uniquely identifying requirements is important so that they might be tracked and undergo the change control process as configuration items. Because requirements often are changed or deleted, having a system to control and account for these changes, as well as the proper documentation to understand the project goals, is extremely beneficial.

As projects progress, requirements eventually become specifications. These specifications similarly should be considered configuration items and linked, through documentation, to the requirements on which they are based. Dong so allows easier tracking of the development of the system. As the project proceeds, documentation should reflect the configuration items, such as hardware or software components, that are used to satisfy particular specifications. All of these items should be linked in a traceability matrix or by use of CM tools. Table 7.2 provides an example of a single record (or row) in a traceability matrix:

Requirement	Specification	Software Modules
R9.1.1	S38.17	DDM031, VSM022, DSM040

Table 7.2 Traceability Matrix

* Gonzalez, "A Guide to Configuration Management for Intelligent Transportation Systems" – April 2002

The system will undergo testing as it is assembled. Results from tests and associated documentation should be considered configuration items as well. Dong so allows managers to easily determine whether or not system requirements have been met. A revised traceability matrix is provided in table 7.3.

Requirement(s)	Specification(s)	Software Module(s)	Test(s)
R9.1.1	S38.17	DDM031, VSM022, DSM040	**VT063**

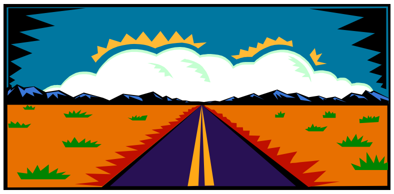
Table 7.3 Revised Traceability Matrix

* Gonzalez, "A Guide to Configuration Management for Intelligent Transportation Systems" – April 2002

Baselines

A number of different baselines will be created throughout the system life cycle. For a full discussion of baselines and their relationship with specific phases of the system life cycle, please see chapter 5.

Chapter 5 addresses CM and the system life cycle



Implementation Guidance Summary

- Configuration management should begin at the concept of operations stage of system development.
- Require consultants and contractors to deliver products that meet the requirements set forth in the configuration management plan.
- Use figure 7.1 to provide guidance for necessary configuration management activities at stages of the system's life cycle.
- Agencies that have started late should not try to "catch up." Simply begin applying configuration management as appropriate for the system's life cycle stage.
- It is rarely too late to implement CM and reap the benefits.

BEST TRANSPORTATION PRACTICES

Considering how transportation agencies have addressed CM during various phases of the system life cycle is useful. Some agencies have specific policies related to the life cycle written in their CM plans, while others simply desire to incorporate as many CM considerations as possible into the process.

Southern California Priority Corridor

The Southern California Priority Corridor CM plan specifies how CM should be incorporated in the design, acquisition, and development of the system. It requires that the CM facilitator ensure that work plans and RFPs use language consistent with the CM plan. Any contractors or subcontractors for projects are expected to follow the procedures outlined in the plan. One of the most important requirements that the plan specifies is that consultants and developers are to participate in audits of the system upon completion of projects.

Similarly, the SCPC CM plan has provisions for the Interface Control Working Group (ICWG) during system development. The leader of the ICWG is required to ensure that RFPs and work plans specify how consultants and developers are expected to perform during development. They are to work with the ICWG to develop the appropriate specifications and documents that will be treated as configuration items.

Richmond, VA Smart Traffic Center

The Richmond Smart Traffic Center uses similar policies when it comes to contracting and system improvement. One particular example of these policies is RFP 717-WB, through which the center sought to retain a system manager to perform system maintenance and administration. In the RFP, there were specific guidelines related to CM that the contractor would be expected to follow.

Because the position is system manager, the contractor is expected to manage CM activities. The system manager is tasked with reviewing and updating the CM plan to outline current policies and procedures. The RFP specified that the system manager play a crucial role on the CCB. The system manager is expected to use the current change-tracking database or propose an improved method.

Also included in the RFP were provisions regarding the specific duties of the system manager as would relate to CM and CCB meetings, including:

- Review all change requests and determine whether they are bugs or enhancements.
- Obtain clarification as needed from the author of the change request.
- Recommend possible groupings of changes that could be combined into a software release package.
- Draft a software release package that includes the following:

- List of all change requests that will be included in the release.
- Rough estimate of the level of effort required to implement the package.
  - List of documents affected by the changes.
  - Test plan indicating whether new test procedures will be used, or if existing software test description documents can be modified for acceptance testing.
  - Training plan, if required, for the software release package, which will specify the amount of training, whether supporting documentation will be needed, and approximately how much time will be needed to train end-users.

(VDOT RFP# 717-WB)

Obviously, this RFP has very specific policies regarding CM because the contractor would be an essential part of the CM program. Basically, the system manager is to follow the procedures in the plan or make improvements where possible.

Georgia NaviGAtor

The Georgia NaviGAtor CM program addresses major issues in the software development life cycle. During each step of the cycle, periodic reviews are performed and a number of documents are produced. Figure 7.3 lists the steps, reviews, and documents associated with the NaviGAtor software development cycle:

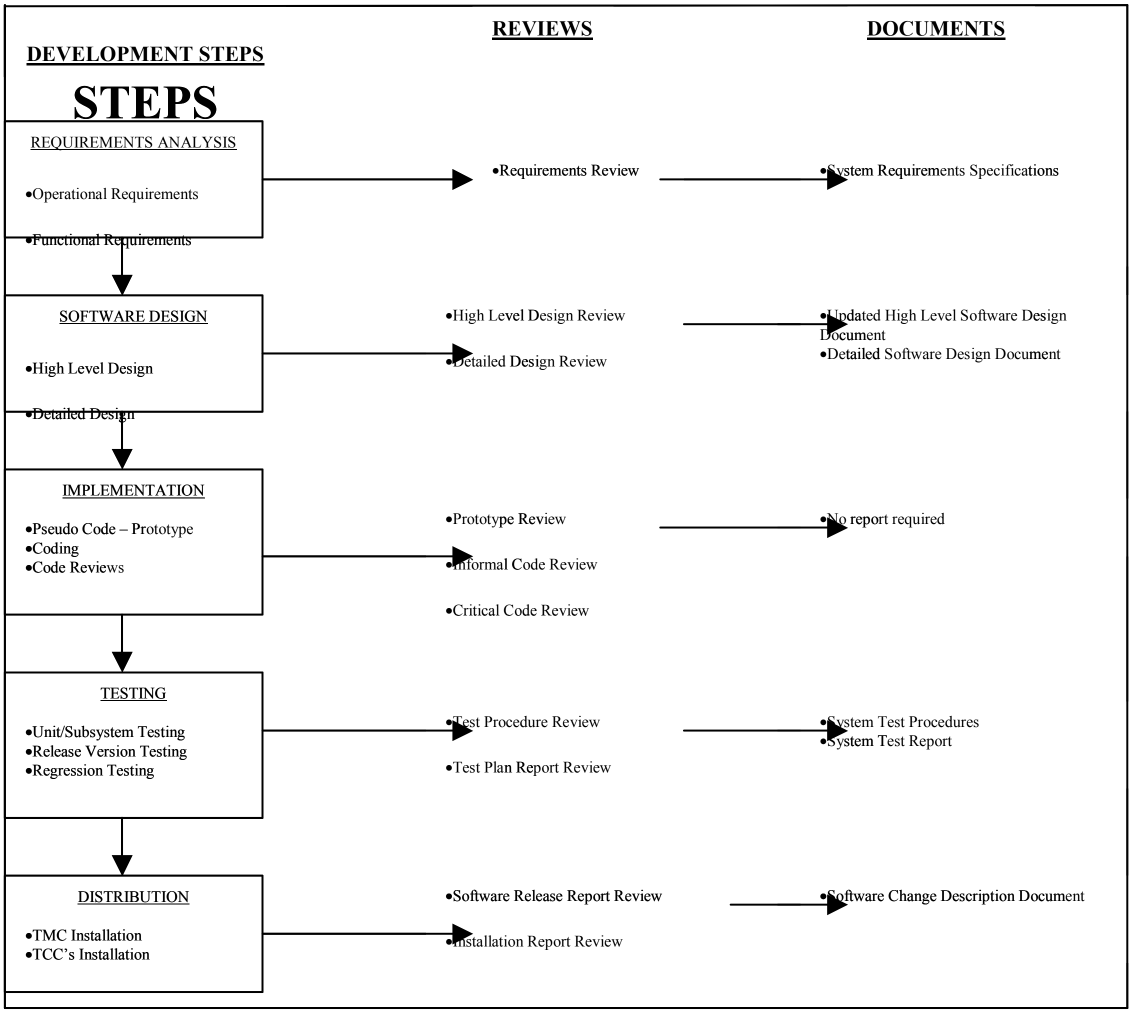


Figure 7.3 NaviGAtor Software Development Cycle

* GDOT NaviGAtor Configuration Management (CM) Manual NAV01-004 – Rev. 5.0: 12/19/01(p. 5-2)

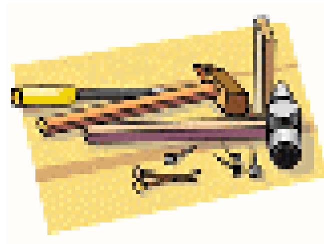
Several major reports are required throughout the software life cycle, representing each of the major phases during development. The required reports are:

1. **System Requirements Specification** – This report specifies the technical requirements for a piece of software for the system. It also should list the means of verification to ensure that all of the requirements will be met. A new System Requirements Specification must be created for each software version.
2. **High Level Software Design Document** – This report describes the general architectural approach to be used on the software configuration item. It is intended to be the predecessor to the detail design and allows requirements to be allocated to components of the software.
3. **Detailed Software Design Document** – This document "completes the description of the software design by detailing the design, behavior and interfaces for all of the software units." All of the units designed are to be traceable back to the original requirements. Upon completion of this report, coding and testing may begin.

4. **System Test Procedures** – This document should outline the test scenarios and test procedures for testing the new software, either on its own or integrated into the NaviGAtor system. All test procedures should be traceable back to the initial requirements and seek to verify that the requirements have been met. New test procedures must be established for each software version.
5. **System Test Report** – This report should describe the testing and results for the particular piece of software and should assess the quality of the software. A new report should be generated for each software version.
6. **Software Change Description Document** – This document is a record of the modifications and defect fixes and the associated System Change Request numbers.

These reports cover all phases of the software life cycle and ensure that the design and development process achieve the requirements specified. It is important to point out that each and every one of these reports falls under configuration control.

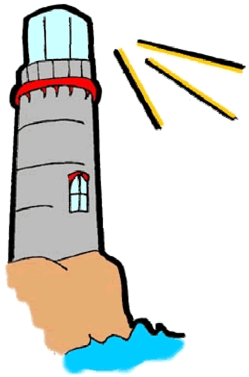
CHAPTER 8 - Configuration Management Tools



This chapter presents an introduction to common configuration management tools and discusses their potential applications. Many of the currently available tools are designed specifically for software development. Some, such as issue tracking tools and document management tools, have relevance in a wider range of CM applications, including TMS. Please note that the International Council on Systems Engineering (INCOSE) maintains a listing of major CM tools and contact information at the following Web URL:

HTTP://WWW.INCOSE.ORG/TOOLS/IEEE1220TAX/CONFIGURATIONMGT.HTML

IMPLEMENTATION GUIDANCE



When considering the selection of a tool, an agency should consider its level of "ownership" of the various TMS components. Lower levels of ownership, as is the case for an agency that has purchased a license for a commercial-off-the-shelf signal control package, often require minimal tools for CM assistance. High levels of ownership, such as when an agency has supported the development and maintenance of a completely custom application, require full support from CM tools.

Furthermore, keep in mind that CM tools are merely *tools*, which often require significant training of agency staff in order to realize their benefits. Agencies must realize that the purchase of a tool is but the first step in using it to support a CM program.

Commonly used CM support tools are described in this chapter. But, specific tools available on the market are not described because of the rapidly changing industry. Readers are advised to use links from the INCOSE Web site to learn more about specific tools.

Issue Tracking Tools

Issue tracking tools (ITTs) are among the most commonly used tools for CM program support. These tools support decision makers in tracking changes as they progress from approval to completion. Most commercial ITTs have features that will automatically generate e-mails to relevant personnel based on the status of a change. One of the most important characteristics of these tools is that they provide administrators the ability to assign changes to various personnel and then track the changes. Some options that are included in many of the tools provide the ability to assign priority to change orders, the ability to customize what is reported in the status reports, and auditing features to ensure that changes are executed as prescribed.

Currently, most TMSs that have a CM program use some sort of issue tracking tool. Some agencies use COTS products while others maintain custom developed, Web-based ITTs. In some cases, simple spreadsheets are used to track the status of changes. Regardless of what type is chosen, ITTs are among the most beneficial tools for a successful CM program.

Document Management Tools

Document management tools can be very supportive of CM programs. With projects often having hundreds of documents in both paper and electronic form, archiving these documents and making them easy to locate and access once archived is extremely important. Software tools that accomplish this task have the potential to shorten project length, save money, and prevent confusion for those involved in the project.

Other document management applications use templates and custom forms to shorten document production time. Items such as a letterhead or an entire technical form may be created, stored, and used again. For CM programs that contain significant documentation or that must adhere to strict standards, applications such as these would be very useful.

Currently, there is little use of these types of systems, although some transportation agencies report that they electronically store drawings and specifications for hardware using a document management tool.

Process-Based Configuration Management Tools

Process-based configuration management tools are intended to facilitate the *software* development and modification processes. These tools act as a central location for all information regarding such effort and seek to minimize confusion among participants about the tasks that they are expected to achieve. Popular applications in this field will document and log software modifications or additions to the system to facilitate backtracking and increase knowledge of the total process. Many programs allow the users to manipulate groups of changes across releases and platforms, automating what can be a painstaking process manually. Software code can be modified on a cross-application basis, rather than on a file-by-file basis. The primary benefit of the process-based variety of tools is the organization that they provide for software modification, greatly reducing confusion among participants and producing a savings of time and money.

These tools can benefit change control similarly as the version control tools or merging tools discussed next. A particularly important aspect of these types of tools is the change log they generate. CM professionals cited change logs as being extremely useful in the event of a major system change or integration.

Configuration Management and Version Control Tools

An important consideration in a CM program is that there will be more than one version of many software applications—representing different baselines for these system elements at various stages of the system life cycle. Version control tools assist the user in resolving the differences in the software applications relevant to their system. Version control tools often prevent or manage concurrent access to the same code files to facilitate concurrent development. Much like merge tools discussed next, version control tools compare two versions and then automatically present to the user a report detailing the major differences, such as changes, additions, removals, moves, and renames. A primary benefit of version control software is that most applications will only save the changes between versions rather than both versions in their entirety, resulting in great savings of memory. Often, these programs allow managers to generate reports for various software developers, informing them of the status of their work or asking them to modify a specific piece of software. The tools have customized interface, which allow for ease of reporting and status accounting.

Numerous TMSs use version control tools, which are extremely helpful to the change control process, often allowing only one user to “check out” a version at a time. Once a user has made desired modifications, the user can compare it to the original version to determine and resolve incompatibilities. Such tools greatly simplify the process of software modification and versioning within a TMS.

Merging Tools

Merging tools are intended for software CM only. Merging tools are software applications intended to facilitate the merging of multiple sources of code into one final set of code. For a user attempting to merge two code sources into one final product, typical merging tools allow the user to view the two sources side by side. With point and click merging, the software typically will highlight differences between the two and ways that the merge would be incompatible. Once the differences and incompatibilities are identified, the user is provided with a variety of editing options to resolve them. Most merging tools employ arrows, linking lines, or other annotation to indicate relationships between the two sources, such as common objects or libraries. Some merging tools also allow the user to compare intentionally modified files with the ancestor file to ensure that the standards employed in the ancestor file are adhered to. These tools are intended to save programming time as they reduce the need for programmers to scrutinize thousands of lines of code to resolve important differences.

Merging tools are relevant for use in TMS change control of custom-developed application software. They aid the change control process by greatly reducing physical examination of source code and allowing programmers to more quickly establish new baselines.

Building Software

As its name implies, building software is intended to aid in the process of building software applications from a variety of components, and thus is intended for software CM only. Often, teams or several individual programmers work together to develop software, causing situations to arise in which the components are incompatible and will not produce functional software. Some building software provides graphical representations of relationships in the code in order to make it easier to understand. Building tools resolve or highlight missing references, build projects in the correct hierarchical order, maintain dependencies between multiple projects, and inform each involved participant when a project has been added to or removed from the application on which they are working. In order to navigate the code, detailed searches allow programmers to pinpoint that which they are looking for without spending significant time manually examining code.

Programming Environments with Versioning

Programming environment tools also is a software-specific CM tool. Such tools can be very useful during software modifications across software platforms. They provide a consistent feel and functionality across heterogeneous systems and across diverse languages. The major operations that can be carried out using a tool such as this are: design, coding, testing, debugging, and maintenance. Some of these tools will allow the user to set a benchmark for testing. After the benchmark has been set, every test from that point on is analyzed for improvements or regressions. The primary benefit of programming environment applications is that they allow programmers to use a common tool on many different projects, producing a savings of training time.

Programming environment tools can be invaluable to the change control process and can eliminate redundancy, a major source of inefficiency. Programming environments with versioning are among the most common tools currently used by transportation agencies to manage custom TMS software.

Infrastructure Relationship Management Tools

Infrastructure relationship management (IRM) tools constitute a relatively new category of CM support resources. They are designed to handle just about every facet of an information technology infrastructure and are suited well for use on ITSs. These tools minimize the effects of organizational change on a system by providing full documentation of items and their relationships to each other, providing up-to-date baselines for disaster recovery, and keeping accurate records of the changes to items and of the current system configuration. One of the primary benefits of these tools over more traditional CM tools is that they are meant to handle both physical and software infrastructure. Items such as cables, signs, gates, and so forth are easily integrated into the system and tracked like all other items. Typically, there is visual documentation of all infrastructures and the connectivity among parts described in detail for purposes of recovery.

These tools provide the ability to assign tasks, track the tasks, automatically generate reports, and change the status upon completion of these tasks. Often, IRM tools are broken into different categories, such as communications infrastructure, physical infrastructure, network infrastructure, and change tracking. Searches may be conducted to locate patterns. For example, if many parts are failing, a search may be performed to determine if a particular vendor or distributor is delivering a high number of faulty parts. This information could be used to inform the vendor or to alter purchase habits. IRM tools generate dozens of different reports based on the needs of the managers.

Miscellaneous Support Tools

To be successful a CM program also must be well supported by basic office supplies/tools, which may be taken for granted. The software-based CM tools described earlier require computer systems to run on. File cabinets and bookshelves must be available to store the large amount of documentation related to a CM program. Agencies are reminded to not neglect these “simple” tools while establishing a CM program.

While CM tools are currently used within many TMSs, some agencies are reluctant to invest in these products. Some of the reasons that were cited for the hesitance to accept tools include cost, fear of increased staff workload, need for lengthy training, and the fact that many of the organizations would need to use only a small portion of a tool’s capabilities.

Almost all respondents who currently use tools for their CM activities say that, while it takes time for acceptance and training, in the long run the tools prove their worth. Although cost is certainly a factor when considering management tools, there is a wide range of products with a broad spectrum of prices. If used properly, the tools eventually save time and money and significantly aid in the organization of a TMS. As far as using only a portion of the tools’ capabilities, agencies seeking a tool that will properly fit their system can choose from hundreds of CM tools available on the market.

BEST TRANSPORTATION PRACTICES

When choosing a CM tool, attention must be given to how well a product fits the agency's needs. GDOT went through an extensive evaluation process in order to eliminate inappropriate products and find the system best suited for its agency. This process is described is this section.

Georgia NaviGAtor

In early 2000 GDOT hired a consultant to compare cable management tools and recommend one that would meet NaviGAtor's needs. The consultant first determined GDOT's requirements for a cable management tool (which could be categorized as an infrastructure relationship management tool as described in the previous section). Next, several manufacturers were contacted to find out whether or not their product would potentially meet these requirements. This initial query narrowed the field down to three contenders, which were further evaluated for their suitability to GDOT's needs.

GDOT first defined its requirements for a cable management tool (CMT):

- Create/delete multiple entries.
- Print a list of entries, vs. printing one entry at a time.
- Customize the print layout (for aesthetic & functionality purposes).
- Query items based on one, two, or even three parameters.
- Print the results of screen-based queries.
- Report printing flexibility.
- Point-to-point tracking of cables or individual fibers or wires within the system.
- Identify unused fiber or cable when given the beginning and ending points.
- Display alternative routing for communication paths if beginning and ending points were identified.
- Unlimited hardware device inventory system.
- Ad-hoc queries and reports on any system element.
- Linked CAD program that would allow the cable plant and other hardware items to be displayed graphically and plotted to hard copy if desired.
- Graphics output using database information for object labeling.

- The cable data and inventory information would be entered once and would be used by various software functions without the need for multiple entries of the same information.
- Multiple security or access levels upon assignment by the administrator.
- Formal and comprehensive training on all facets of the product.
- Phase 1 beginner training and phase 2 advanced training desired.
- Full documentation of the product for reference and training.
- Local (Atlanta) technical support.

The consultant then contacted the known CMT manufacturers (shown in table 8.1) for an initial query based on these requirements. (All tables and user statements that follow have been reproduced from TransCore's "Cable Management Tool Evaluation Report" and "PLANET Cable/Equipment Management Tool Evaluation" to GDOT.)

Company Name	Product Name
Advanced Technology Corporation 5 Concourse Parkway Suite 2800 Atlanta, GA 30328	ATC
Auto-Trol Technology 2180 West State Road 434 Longwood, FL 32779	KONFIG
Cablesoft Inc. 1501 W. Fountainhead Parkway Suite 520 Tempe, AZ 85282	CRIMP for Windows
Fluke Corporation 6920 Seaway Blvd. Everett, WA USA 98203	Cable Manager
IMAP Walnut Creek CA (800) 978-3430	IMAP CMS
IntegraTrak Inc. 12600 S.E. 38th St. Suite 250 Bellevue , WA 98006	ITS Cable Management
ISI Infortext 1051 Perimeter Drive Shaumburg, IL 60173	Infortel For Windows
Network Information Systems MATSCH Systems 911 North Division Grand Rapids, MI 49503	Matsch CFMS
Planet Associates, Inc. 485C Route 1 South Suite 100 Iselin, NJ 08830	PLANET
RIT Technologies 900 Corporate Drive Mahwah, NJ 07430	Enterprise 1
Telco Research 616 Marriott Drive Nashville, TN 37214	TRU-Server PWA
Veramark Technologies 3750 Monroe Avenue Pittsford, NY14534	TMS

Table 8.1 Manufacturers Evaluated

*Please note that the information in this table was current as of early 2000 and may no longer be accurate.

This initial inquiry process narrowed the field down to three products. The consultant created the comparison matrix displayed in table 8.2, which includes cost, ease of learning/operation, and support. It is important to note that some elements of a software product are licensed by size, such as the elevation views for equipment racks; the licenses are sold in 50 rack modules for about $6000 per module plus maintenance. Furthermore, ownership also has a cost. For example, the maintenance charges for Planet are 17.5 percent of the purchase price for the first year. There is the possibility of buying forward on the maintenance (three or four years).

	Manufacturer #1	Manufacturer #2	Manufacturer #3
Cost for 20 concurrent users with unlimited connections			
Additional software required for desired configuration			
Cost for additional software			
Who supports additional software			
Yearly maintenance costs			
Maintenance percentage			
Training costs On-site (Atlanta)[1]			
Training costs Off-site			
Days of training for implementation personnel			
Days of training for users			
On-site implementation cost estimate per day			
40 hours of on-site consultation			
40 hours of off-site data manipulation			
Phone assistance charges during implementation			
Upgrade policy within version			
Customer support hours			
Toll free support phone			
Support calls limitation			
Assigned support specialist.			
Full-time support specialists on staff			

Table 8.2 Supplier Comparison Matrix

1 All on-site activities require additional chargers for on-site personnel travel and expenses.

While such a matrix is helpful for a structural comparison, user statements sometimes offer a more in-depth impression of a product. During the evaluation process, user comments tended to focus on how *intuitive* a product was to learn and use; that is, how easy and understandable it was. This focus area included such features as the user interface (was it friendly?); ability to manipulate graphical representations of data; and accessibility of support. Attention to these details during the evaluation process increases operator efficiency and maximizes product utilization in the long run, as well as minimizes training expenses and the need for support. Remaining user comments focused on the functionality of the system with regard to GDOT's particular needs. This stage of the evaluation eliminated one of the three products, prompting the consultant to create a final product comparison chart (shown in table 8.3), in which the two finalists were rated according to their suitability to GDOT's context.

Evaluation Criteria	Manufacturer #1	Manufacturer #2
On-Screen GUI usefulness		
Ease of creating database objects		
Efficient graphical drill down capability		
Automated data entry		
Print what is on the screen		
Report printing flexibility		
Ad-hoc queries and reports on any system element		
Point-to-point tracking of cables or individual fibers or wires within the system		
Identify unused fiber or cable when given the beginning and ending points (inspect conduit)		
Graphic Circuit Tracing		
Unlimited hardware device inventory system		
Ability to display and print CAD graphics with network objects displayed and identified		
Advanced CAD Graphics capability		
Provide for the creation of physical objects that can be saved and duplicated throughout the network		
Multiple security or access levels upon assignment by the administrator		
Multi-user read write capabilities		
Formal and comprehensive training available for different user levels		
Full documentation of the product for reference and training		
Technical support response		
On-line help (in program)		
Local (Atlanta) technical support		
TOTAL		

Table illustrates manufacturers' compliance to the TransCore-developed evaluation criteria. The evaluation criteria shown are both the original GDOT cable management requirements with additional requirements (shown in *italics*) developed during the evaluation process. The additional criteria are shown in italics. Each product is rated on a compliance scale of 0 through 3, with 0 equaling Non-Compliance, 1 = Minimal, 2 = Acceptable and 3 = Good.

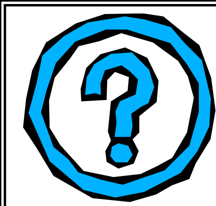
Table 8.3 Final Product Comparisons

CHAPTER 9 - Resources to Support Configuration Management Programs

The purpose of this chapter is to introduce available resources for to support the personnel requirements of configuration management. Transportation professionals currently involved in CM are quick to point out that the effectiveness of a CM program is entirely dependent on the people who are involved. This chapter addresses training and development needs and opportunities for agency staff and also discusses the use of consultants to supplement agency personnel in a CM program.

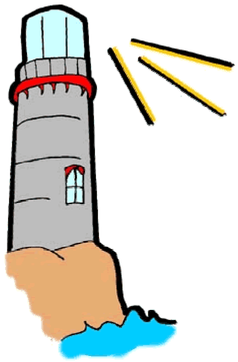
CONFIGURATION MANAGEMENT TRAINING

Principle 5 of EIA 649 recommends that organizations “conduct training so that all responsible individuals understand their roles and responsibilities and the procedures for implementing configuration management processes.” By conducting training agencies ensure that all personnel involved with the CM program understand the goals of CM as it relates to their system and exactly how the program will be carried out. According to EIA 649 an ideal training program should involve a detailed review of the CM functions that a particular individual is involved in, as well as cross training with other disciplines/CM functions. Furthermore, key technical personnel require in-depth training in CM processes and the use of CM tools.



Chapter 6 includes detailed information on recommended knowledge, skills, and abilities for staff involved in CM.

IMPLEMENTATION GUIDANCE



This section presents general recommendations for CM training. Subsequent sections provide detailed information concerning currently available training opportunities.

Awareness-Level Training

All management, design, development, and maintenance personnel must receive awareness-level training to familiarize themselves with the basics of CM before they are expected to become involved with implementing the program. Note that management levels above TMC management also should be included in the awareness training given upper management's role in resource allocation and project determination and programming. Short, half- or full-day awareness-level courses are recommended. In most cases, either internal agency personnel with significant CM experience or CM consultants would serve as good instructors for the course. Awareness-level courses should include the following topics at a minimum:

- Introduction to CM.
- Why CM is important to the agency.
- Introduction to the Agency's CM program.
    - Configuration identification.
    - Change control.
- Explanation of agency-specific procedures.
    - Forms.
    - Role of CCB.

Targeted Training

Personnel essential to the CM program, such as those serving on the CCB or otherwise directly involved with recommending or making changes, require extensive, targeted training. Personnel requiring targeted training are advised to take a weeklong seminar on CM, which provides in-depth exposure to the processes and intricacies of CM. The courses presently available for this level of training are heavily software-oriented, but are the best choice until more general, detailed CM courses become available.

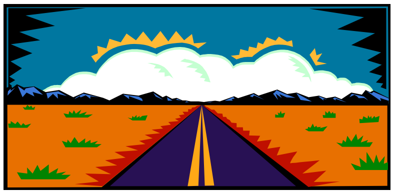
Beyond a weeklong CM processes course, many personnel require vendor-provided training in the CM tools used by the agency. Given the complexity of these tools, personnel directly responsible for working with the tools should take advantage of training opportunities to ensure their effective application.

Continue Training

Training must be ongoing. Agency staff will require training refreshers as the CM program evolves and as new tools are implemented. Refresher training does not require as many resources as the initial training and usually can be accomplished in a less formal manner.

CM Manager = Training Manager

One person should be responsible for developing and implementing the CM training program for an agency. The person best suited for this role is the CM manager, given that he or she best understands the roles and responsibilities of the various individuals involved in the program.



Implementation Guidance Summary

- Provide awareness-level training for all staff involved in CM.
- Provide targeted training for key staff with essential CM responsibilities.
- The CM manager should lead the training program.
- Training must continue as the CM program continues.

BEST TRANSPORTATION PRACTICES

Some agencies have developed detailed procedures to guide their CM training efforts, while others rely on informal, internal programs in which experienced staff provides guidance to newer members. As with any component of a CM program, training should be oriented to the needs of the agency in question. The following is a description of the training programs currently in use by several agencies.

<u>Georgia NaviGAtor</u>

The Georgia NaviGAtor CM program includes provisions for training all involved personnel, including the members of the CCB, administrators, technicians, and consultants. Most training involves half-day courses that provide basic introductions to the various processes involved with CM. Further training is conducted by sections based on the assessment of need by section managers and the CM manager. For example, personnel in the information technology section require more detailed training in the software tools that are used in the CM program.

Although the training program has proven to be adequate, a key lesson learned was that a significant learning curve is associated with adoption of CM. For this reason, the training program is essential. As stated by the CM manager, “CM was used on projects relatively soon. But training and experience were needed for it to be effective.”

The NaviGAtor CM plan defines specific guidelines regarding training of personnel. These guidelines, presented below, provide excellent guidance to those developing CM training programs:

1. All training will be conducted by the CM advisor, CM manager, his designee, or a combination thereof,
2. The CM manager will determine training requirements for the year. This may include new CM manual procedures, standard operating procedures, training for new employees, or a refresher course on existing procedures.
3. Section managers may determine any additional CM-related training that their employees need and advise CM manager of these requirements.
4. A notice of training will be provided to the scheduled employees and their section manager at least two weeks prior to the training session.
5. Training classes should be structured to include examples of real life problems and situations as they relate to the attendees’ jobs and CM principles.
6. Attendance should be taken at meetings with follow-up to appropriate managers as to meeting results.

Georgia Navigator CM Manual – 12/19/01- (p. 3-12)

Southern California Priority Corridor

Caltrans provides training to all personnel involved with CM on the Southern California Priority Corridor project. A variety of short courses are offered in the basics of CM and in the use of the tools involved with the CM program, such as the issue-tracking tool. Management personnel are trained in the administrative aspects of CM. The CM Subcommittee chairperson is responsible for overseeing the training that is associated with CM.

CONFIGURATION MANAGEMENT COURSES

This section provides a description of CM training options available at the time of publication of this guidance document. The vast majority of off-the-shelf courses are only available for software CM. While there are a variety of detailed courses of two or more days, there are very few half- or full-day courses. Some courses offer the option of being taught at the clients' place of business. But most are located at professional educational centers. There is a broad range of prices, varying by course length and level of detail. The following list is for illustrative purposes only: it is not exhaustive and will change over time.

1. Learning Tree International

http://www.learningtree.com/us/ilt/courses/342.htm

Learning Tree International offers a four-day, in-depth course in software CM. The firm states that attendees will learn how to:

- Implement configuration management (CM) processes.
- Determine the appropriate level of CM for user needs.
- Determine roles for CM team members.
- Use tools for CM purposes.
- Define the content and scope of a configuration management plan.

The course is intended for management and technical personnel involved in any stage of the software development or maintenance process. The course is divided into separate workshops that include:

- Identifying configuration items.
- Evaluating change proposal impact.
- Preparing a release checklist.
- Using the repository to answer questions.
- Forming configuration control boards.

- Reviewing CM plans.
- Preparing a CM strategy for a Web site.

The foundation of the course is rooted in software industry standards for CM, so it likely is similar to many other software CM courses.

2. Process Improvement Associates

http://www.processimprovement.com/courses/SCM2.htm

Process Improvement Associates offers a two-day workshop, which offers the basics of software CM, most notably:

1. Planning.
2. Identification.
3. Change control.
4. Configuration status accounting.
5. Configuration verification and audits.

Though the primary focus of this course is on software development, the course also deals with design and test documentation, COTS products, and other items associated with software-based systems.

The course is taught using a number of government and industry standards such as J-STD-016, US/ISO 12207 and EIA 649. One of the primary objectives of the course is to identify the key components of a CM plan so that class participants will be able to develop their own. Topics from process description to CCB establishment are covered in this effort. Other objectives of the course include introducing participants to various CM software tools, instructing them in the baselining process, and introducing them to the concept of a central software library with checking in/out privileges.

3. Integrated Computer Engineering

http://www.iceincusa.com/training_cm1.htm

Integrated Computer Engineering offers a half-day course, which presents the knowledge, techniques, and tools necessary to control and manage across activities, organizations, and individuals. The stated purpose of the course is to help those responsible for software systems acquire the knowledge and skills necessary to manage software information and configurations. At the end of this course, participants should be able to:

- Understand the fundamental concepts of software configuration management.
- Explain how to define and develop a process for managing information.
- Understand how to manage information in their organization.

The course outline consists of the following topics *(as stated on Web site)*:

- Why configuration management is important.
- Configuration management and software engineering.
- Configuration management planning.
- Configuration item identification.
- The change control activity.
- Status accounting.
- Configuration audits.
- Subcontractor control.
- Configuration management tools.
- Operations and maintenance.

The course is intended for middle management, lower-level management, project staff, and CM personnel.

4. Charles Maier Associates

http://freespace.virgin.net/charles.maier/training/CM.html

Charles Maier Associates offer a two-day course covering all aspects of CM including hardware, software, and document control. It is intended to provide the basics to management personnel as well as technical staff from a variety of fields. For management the course demonstrates the benefits and costs of CM. For technical personnel the basic principles involved in a CM program are introduced and developed. The importance of international and industry standards also is stressed. Some of the basics that are discussed include *(as stated on Web site):*

- Lifecycle management.
- Configuration identification.
- Status accounting.
- Change control.
- Configuration audits.
- Versions, variants, deltas, and baselines.
- Logistics of distribution and control.
- Problem management principles.
- Planning and earned value.
- Change control boards.

The course is divided into nine separate modules of classes over the two-day duration.

CM STAFF DEVELOPMENT – WEB RESOURCES

To supplement formal CM training, CM Web sites offer basic CM information for personnel. The number of CM sources available, and even the number of sources in the full literature review compiled for this project, may seem overwhelming. This guide seeks to highlight the best Web resources for someone new to CM, so that after reviewing these sources, he or she will have not only a sense of what CM is, but also an introductory understanding of how it works.

> A full literature review for this guidance document is presented in appendix B.

Although most CM Web sites contain introductions to configuration management, two serve this purpose especially well. Theses sites introduce the fundamental ideas behind CM, briefly discuss its major components, and point out why CM is appropriate for complex information technology-based systems.

1. "What is Configuration Management?"
   http://www.pdmic.com/cmic/introtoCM.shtml
2. "CM 101"
   http://www.cmtimes.com/CM%20101/intro_cm_101.htm

These sites also are useful because they define all relevant configuration management vocabulary in an easy-to-understand manner, which enables the reader to understand more detailed configuration management Web sites.

After learning the basic concepts and terminology of CM, becoming accustomed to the major CM components that follow a product through its life cycle is useful. The resources best suited to this are CM standards, such as EIA 649. The following Web sites also provide good information on the overall CM process.

1. "CM Plans: The Beginning to your CM Solution"
   http://www.sei.cmu.edu/legacy/scm/papers/CM_Plans/CMPlans.MasterTo C.html
2. "Configuration Management Plan – Model Text"
   http://www.airtime.co.uk/users/wysywig/cmp.htm
3. "TWRS Configuration Management Program"
   http://www.hanford.gov/twrs/cmpp/cmpphome.htm
4. NASA Software Configuration Management Guidebook"
   http://satc.gsfc.nasa.gov/GuideBooks/cmpub.html

CONFIGURATION MANAGEMENT CONSULTING SERVICES

It is common practice for transportation agencies to retain a configuration management consultant to help develop and implement a CM program. In most cases, the consultant sits on the CCB, helping the CCB chair make decisions regarding changes to baselines and providing administrative support. This section provides a description of services typically provided by consultants in development of the CM plan and in day-to-day support, as well as a discussion of criteria that should be considered when selecting a configuration management consultant.

Configuration Management Plan Development

In most of the agencies that were surveyed, a large percentage of the consultants' time was devoted to developing the CM plan. The time spent developing these plans varied widely depending on the complexity of the TMS and the demands of the agency. For example, the Georgia NaviGAtor CM manual took a full-time consultant approximately two years to finish, and nearly another year to revise. Plans developed for agencies that wanted to manage only software took a full-time consultant only two weeks to develop.

The CM team for the NaviGAtor program learned a useful lesson while developing its plan. The CM plan was originally commissioned in 1997 and took the first consultant almost two years to develop. The plan marked one of the first attempts on behalf of a DOT to develop a CM program specifically to manage all components of an ITS. It was designed by a consultant who gained CM experience while in the military, but who did not have experience in any other sector or industry. Unfortunately, the original version of the plan was deemed unfit for the NaviGAtor program's needs after being used for approximately one year. GDOT's CM manager stated that the plan went into too much detail and was not tailored to the DOT environment. Furthermore, he stated that the plan delved too extensively into "what-if" scenarios that probably would never take place.

After realizing the inadequacy of the original CM plan, GDOT hired a new consultant to solve these problems. This consultant had 30 years experience working with CM in different environments, including commercial products, telecommunications, and rail. By evaluating the flawed system and talking to many agency personnel, the consultant was able to successfully tailor a CM program that met the agency's needs. The consultant mainly relied on personal knowledge and consultation with DOT personnel that were familiar with the system he sought to manage. He also consulted outside resources, such as books and standards, but not to a large extent.

The Richmond STC CM plan—which manages only software, not field equipment—took two weeks to develop. Since the CM program's recent initiation, no major modifications to the program have been made. The agency used standards, consulted other DOT projects, and relied heavily on the personal experience of the consulting team it hired, which had experience developing CM programs for the U.S. Department of Defense, the U.S. Department of Energy, and in the private sector. The consulting team reviewed existing plans it found on the Internet and selected the parts it felt were relevant to the STCs needs. By consulting key personnel involved in day-to-day operation of the TMC, the consultants evaluated what would help them to maintain consistency in the system.

Operational Support

Most of the consultants that were hired to develop CM plans began serving as support staff to the CM manager after the plan was completed and the CM program instituted. In most cases the consultant sits on the CCB and works closely with the CM manager to evaluate change requests and, in some cases, to assist in implementing the necessary changes. The primary consultant for the Georgia NaviGAtor program continues to work full-time on the CM program. Currently, his main responsibility is working to establish a baseline for the entire ITS infrastructure, which includes all field devices, software, hardware, and documentation. He estimated that he spends 25 hours per week training personnel on how to document each item, establishing procedures for baselines, and providing quality assurance to make sure those procedures are being followed. He spends the remaining time in the workweek helping the CM manager with training, sitting on the CCB, conducting independent audits, and evaluating change requests. A consultant who works for an agency that focuses on managing change in software estimated that he spends about two hours a week tracking proposed changes in the software, evaluating effective fixes, and fixing problems with the code. He also spends a full day every month attending a meeting of the CCB, of which he is a member.

CM Consultant Selection Criteria

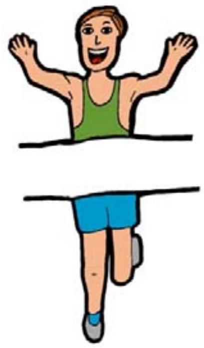
A critical step in developing and maintaining an effective CM program is choosing a CM consultant that is capable of meeting an agency’s needs. By combining information gathered from interviewing numerous CM managers, some clear selection criteria have been identified.

The prospective CM consultant should have extensive experience with CM and its guiding principles.

The consultant should have experience setting up CM in multiple application domains if they do not have experience in surface transportation. This requirement, however, is not necessary for all CM applications in the ITS environment. For example, agencies that are interested primarily in developing a custom software system and having a consultant manage change during the development phase should be more focused on finding a consultant with a reputation for a having a sound technical approach and less on CM practices, which are now highly integrated into software engineering. The Richmond contract team focused its evaluation of prospective clients on the amount of software development experience each had, their knowledge of programming languages, and their level of education before considering their experience with CM.

Agencies should ask for references from prospective consultants in order to gauge their level of familiarity with the process and experience in setting up systems.

CHAPTER 10 - Conclusion



The importance of CM in establishing and maintaining a functionally sound TMS cannot be overstated. For agencies questioning whether or not establishing a CM program for a TMS is really appropriate, the answer is a resounding "YES!" Keep in mind, however, that CM can consume significant amounts of staff time and money. For this reason, developing a CM program that fits the needs of a particular system is vital to its success. In other words, CM programs are not one-size-fits-all entities.

Because of the breadth of this document, readers may think that CM is too large an undertaking to be worth it for his or her system or that the agency cannot possibly implement such a program. Although CM, and its complexity, can and should grow as a system grows, it does not need to include each and every item described in the guidance document. The purpose of this concluding chapter is to distill all the guidance information and recommendations provided in this document into a small number of essential guiding principles of a CM program. The following nine principles have been selected from the 50 guiding principles provided in EIA 649 and serve as a starting point for any TMS.

CM IN TMS GUIDING PRINCIPLES
WHAT THEY MEAN TO YOUR TMS

Each of the guiding principles is presented in this section, followed by a discussion of how the principle applies to a TMS CM application.

1. Identify the context and environment in which CM is to be implemented and develop an appropriate CM plan accordingly.

   This principle emphasizes the fact that a CM program must begin with a plan that carefully considers the needs of the TMS. It illustrates that an agency must devote time and resources to CM planning and that it must produce a tailored document. Simply using a "standard" or existing plan will result in a generic program that does not meet the system needs well and will likely not receive buy-in from staff.

2. Define procedures describing how each configuration management process will be accomplished.

   CM is not a mysterious or highly technical undertaking. In fact, a CM program can suffer because people think of the related activities as basic common sense. Although this is true in many ways, if people simply rely on common sense rather than follow established, clearly defined procedures for a CM program, employees periodically will let key items (such as documentation or change consideration) slip. A key benefit of a CM program is that best practices in documentation and change control, which professionals already know to be "good ideas," become institutionalized. By documenting required CM procedures, the integrity of the system is protected by introducing consistency. A system with non-standardized procedures can lead to miscommunication between departments and can undermine the entire CM program, because enforcing principles that are not formalized is impossible.

3. Conduct training so that all responsible individuals understand their roles and responsibilities and the procedures for implementing configuration management processes.

   CM is not necessarily fun for those who have to make it work for an agency. It requires careful documentation management and will, at times, slow down an eager maintenance or development employee with a "hurry-up-and-do- something" attitude. For this reason, CM often faces resistance when introduced to an organization. Training is essential to: (1) convince employees of the value of CM and (2) clearly describe and demonstrate the CM procedures used by an agency. Most training does not need to consist of weeklong vendor seminars. Rather, short awareness-level training and targeted procedural training are most important. In many cases, this level of training may be provided well by in-house personnel.

4. All items are assigned unique identifiers so that one item can be distinguished from other items.

   Identification is the starting point for CM. TMSs are complex systems with many interrelated components. In order to effectively manage change and protect the integrity of the system, people must first be able to clearly identify each individual component. Thus, when a change is considered, all responsible parties clearly understand what elements of the system will be impacted. A complicated numbering system is not necessary to create unique identifiers. The essential element is to develop at least a minimal identification system and then use it throughout the life cycle of the system.

5. Configuration documentation defines the functional, performance, and physical attributes of a system.

   Maintenance of system documentation is one of the most overlooked, relatively simple activities of CM in TMSs today. Without sound documentation other CM processes simply cannot occur. Careful attention to acquiring documentation, associating it with the proper component identification, and maintaining the documentation is essential for CM. In small-scale TMSs, this activity may be as simple as establishing a spreadsheet catalog to refer to a physical or digital library. As CM programs become bigger, document management tools become essential to support this activity.

6. A baseline identifies an agreed-to description of the attributes of an item at a point in time and provides a known configuration to which changes are addressed.

   Baselines are the fundamental to configuration management. Careful attention to establishing and maintaining sound baselines at appropriate times in a system life cycle ensures the stability and availability of the TMS. In addition, it is important to remember that the baseline refers to the system components along with the related documentation. Thus, a version of application software without its associated documentation is insufficient to serve as a baseline. With a sound baseline in place, changes can be thoroughly considered before implemented. Furthermore, if a change results in an unanticipated problem, the baseline may be used to quickly reconfigure the system back to a stable state. Baselines must be established and maintained in a CM program, large or small. In simpler cases, baselines can be well managed with a spreadsheet and careful oversight. Larger systems baselines should be managed with a CM tool.

7. Each change is uniquely identified.

   This deceptively simple principle reflects the core of CM – identify and document anything that impacts the TMS. Thus, it is important to identify and document every change made. Why?

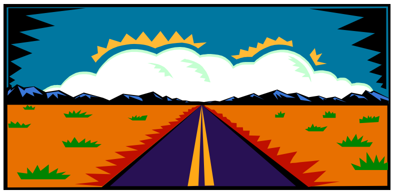
   - It is important to keep a history of what works and doesn’t work. If a change works well, the details of the change should be available to guide future changes. Likewise, failed changes should be avoided.
   - Changes tend to repeat themselves. By keeping a history of changes, new staff, contractors, and so forth can learn from past experience and investment.
   - Change is directly related to configuration.

8. Consider the technical, support, schedule, and cost impacts of a requested change before making a judgment as to whether or not it should be approved for implementation and incorporation in the item and its documentation.

   A common misperception of CM is that it only deals with the technical aspects of a system. This principle makes it clear that in the process of change control, key, non-technical issues must receive careful consideration. There are numerous examples of effective technical changes made to TMSs that could not be effectively supported by a transportation agency over the life cycle of a system. By carefully considering, for example, future support implications of a change during the change control process, CM can help to prevent changes that may not be sustainable. Of course, understand that the CM process itself doesn't ensure this. Rather, those involved in the CM program, such as members of the CCB, must be committed to carefully considering all aspects of proposed changes before approval.

9. Implement a change in accordance with documented direction approved by the appropriate level of authority.

   This principle may be stated more simply as "follow the process." There is a constant temptation to implement changes under the table, without going through the formal CM process. People want to avoid the delay and perceived administrative burdens of following the CM process. Yet bypassing the process weakens the program and threatens the stability of the system. This principle points to the critical need for buy-in from all involved in the TMS.



CM in TMS Guiding Principles

- Identify the context and environment in which CM is to be implemented and develop an appropriate CM plan accordingly.
- Define procedures describing how each CM process will be accomplished.
- Conduct training so that all responsible individuals understand their roles and responsibilities and the procedures for implementing configuration management processes.
- All items are assigned unique identifiers so that one item can be distinguished from other items.
- Configuration documentation defines the functional, performance, and physical attributes of a system.
- A baseline identifies an agreed-to description of the attributes of an item at a point in time and provides a known configuration to which changes are addressed.
- Each change is uniquely identified.
- Consider the technical, support, schedule, and cost impacts of a requested change before making a judgment as to whether or not it should be approved for implementation and incorporation in the item and its documentation.
- Implement a change in accordance with documented direction approved by the appropriate level of authority.

APPENDIX A - Description/Summary of EIA 649

The purpose of this appendix is to provide a brief description and summary of the Electronic Industries Alliance (EIA) Standard 649 *National Consensus Standard for Configuration Management* (ANSI/EIA-649/-1998) – EIA 649.

The document begins with a brief introduction to CM and a history of the Standard itself. It then proceeds to an explanation of its terminology, which includes both definitions and a list of synonymous terms that are used in other standards. EIA 649's purpose is to provide principles that are applicable to a broad range of industries. The document's scope states that the Standard seeks to explain the major CM functions throughout an item's life cycle. Some of these functions are:

- CM planning.
- Configuration identification.
- Configuration change management (change control).
- Configuration status accounting.
- Configuration verification.

* Note: EIA 649 uses the word "item" while the terms item, component, or system may be applicable for TMSs.

CM Planning

The first step in planning an effective CM system is to identify the system's environment. The Standard emphasizes that different environments have different CM needs, and that its principles must be applied selectively. The Standard goes on to list the points that must be identified by an effective CM plan. Although the remaining sections in the Standard's CM planning chapter list elements necessary for CM planning, they do not detail how these elements, such as implementation procedures, training, and performance measurement, should be carried out because, once again, the Standard states that each environment will have different needs.

Configuration Identification

This chapter in the Standard covers how elements in the system, such as items, documents, and materials, should be described. The first section covers item information, which should include information on an item's performance, functionality, and physical attributes. Subsequent sections provide a detailed discussion on how the item's composition should be documented and why a systematic approach, for example, consistent numbering, is necessary. The Standard then states that document identification is necessary for an easily navigable system in which documents can be retrieved as needed.

The next section of the Standard provides a discussion on baselines, which includes a definition, how to establish baselines, and their purpose. The last two parts of the configuration identification section relate to specific applications of item documentation, emphasizing the need to maintain current documentation for all items, as well as items that are used from outside sources.

Configuration Change Management (Change Control)

This chapter covers subjects regarding how to identify when a change is necessary, how to evaluate it, and how to implement and verify this change. This section emphasizes that changes should be accomplished using a measurable process. The Standard stresses that each change should be separately identified and details how to ensure this principle is accomplished. Another facet of change control that is considered in the Standard is management of change evaluation. It recommends that all aspects of a change be considered before a change is approved. These aspects include the impact of the proposed change, its effectiveness, cost, and who has to give final approval. The last part of this chapter points out that an organization, when approving a change, must ensure the change is carried out correctly and that it is appropriately documented.

Configuration Status Accounting

The purpose of configuration status accounting is to provide an accurate database of information regarding an item and its associated documentation. Principles in this section detail the need to systematically record information that is validated and safeguarded. Also, a section describes what should be documented at each phase for an adequate configuration status accounting system.

Configuration Verification

The purpose of configuration verification is to make sure that the item's requirements have been met, and that is has been correctly documented at each baseline. The first parts of the section describe how to judge whether an item and its associated documentation are adequate. Also included is a principle that states periodic reviews of the configuration are necessary "to identify and monitor changes or degradation of performance, or to compare existing elements with new criteria or requirements."

Following the main section are the appendices, which include a list of all the principles in the Standard, as well as a discussion of how EIA 649 relates to other CM standards.

APPENDIX B -
Annotated Bibliography

These materials focus on the concepts of configuration management, and are not focused on one particular aspect.

Web sites

1. "CM 101"

   URL: http://www.cmtimes.com/CM%20101/intro_cm_101.htm

   CM 101 is a series of Web pages that promises a general introduction to configuration management, although it is largely focused on change control. The first page contains a diagram that highlights the main parts in the configuration management life cycle and a brief description of each. The second page contains a decision flow diagram for the entire configuration management process. The subsequent pages detail each decision in the diagram and explain its use. Overall, this site is a good introduction to change control, but does not adequately introduce the other configuration management features.

2. Lyon, David D. "On Configuration Management and Program Management." PDM Information Company, November, 2000.

   URL: http://www.pdmic.com/cmic/publications/pmforum.shtml

   This article provides a simplified definition of configuration management and goes on to relate it to data management. The author provides an example of an automated configuration management system that consists of one database, which stores all final versions of products and their baselines. The author goes on to state that configuration management is essentially the same as data management, and that the configuration and project manager positions will eventually be the same.

3. Daley, Jack, Fred J. Bahrs & Mike Gearhart. "What is Configuration Management?" PDM Information Company.

   URL: http://www.pdmic.com/cmic/introtoCM.shtml

   This Web site attempts only to provide the reader with an overview of configuration management. It is a good resource for those who might have heard of configuration management, but do not know what it is. In its seven pages the paper touches a number of topics including why configuration management is useful, how to implement it, a definition of CM, and its major components. Although an informative summary, this paper is not intended to be a resource for CM design.

Books

Books currently in print

1. Monahan, Ray E. *Engineering Documentation Control Practices and Procedures*. Marcel Dekker, Inc. New York, NY. 1995.

   Engineering Documentation Control Practices and Procedures focuses on configuration management from the perspective of private industry responsible for supplying a product to a client. The first chapter provides an introduction to configuration management terminology, along with the aspects of good configuration management, and its objectives. Chapter two describes configuration planning and provides a brief discussion of a baseline system. Chapter three describes the entire configuration management process, and a detailed outline is included. Although much of the book is not directly applicable to the transportation industry, chapters eight through twelve contain highly useful information regarding changes to an already developed configuration. After defining the types of possible changes, the author focuses on non-interchangeable ones and how a good configuration management system deals with them. The last section of the book is devoted to describing how and when to use automated configuration management systems. An appendix lists companies that provide software packages.

2. Mikkelsen, Tim & Susan Pherigo. Practical Software Configuration Management: The Late Night Developer's Handbook. Prentice Hall. Upper Saddle River, NJ. 1997.

   Practical Software Configuration Management provides a very practical introduction to configuration management. It begins with an introduction to principles of configuration management, as well as a discussion of fundamental concepts and terminology. The next section discusses practical issues from both the individual user and team perspectives. The last part of the book focuses on configuration management tools, describing many public domain and commercial tools. Of particular interest to transportation management is the book's discussion of the use of configuration management during system operations and maintenance (not just development). The book also comes with a CD-ROM, which includes configuration management tools to provide the reader with opportunities for hands-on experience.

3. Watts, Frank B. *Engineering Documentation Control Handbook: Configuration Management in Industry*. William Andrew Publishing: Norwich, New York. 2000.

   Unlike the vast majority of books available on configuration management, *Engineering Documentation Control Handbook* focuses entirely on configuration management in industry. The author focuses on a simplified, fast configuration management system, which conforms to, and usually surpasses, DOD standards. The chapters titled "Change Control" and "Fast Change" give an exceptional explanation of how to handle configuration modifications. In these chapters the author gives a detailed description of how to set up a system that allows the fastest possible changes to take place. Also, many case studies are provided, which impart further insight on how to implement the correct system for a given situation. Overall, the book is very easy to understand and serves as an excellent introduction and handbook to a configuration management system for industry.

Books currently out of print

4. Buckley, Fletcher J. *Implementing Configuration Management: Hardware, Software, and Firmware*. IEEE Computer Society Press. Los Amalitos, CA. 1996.

   Implementing Configuration Management is well suited for transportation professionals because it directly addresses configuration management in software/hardware systems. The first chapter provides a general description of configuration management and a definition of the purpose to "maintain the integrity of the product throughout development and production cycles." Chapter two provides a description of the configuration management environment, which includes development and production. Chapter three covers configuration management planning, including the development of a plan and the associated procedures. The remainder of the book details each step of the configuration management process. An appendix contains definitions, acronyms, and abbreviations. A particular strength of this book is that it provides example configuration management plans: a general plan and a plan for a fictional power plant. The power plant configuration management plan is very similar to that of transportation management systems.

5. Samaras, Thomas T. & Frank L. Czerwinski. *Fundamentals of Configuration Management.* Wiley-Interscience. New York, NY. 1971.

   One of the first books available on configuration management, *Fundamentals of Configuration Management* is concerned primarily with basic, introductory material. Like most introductory CM publications, the book begins with an introduction to CM terms. Yet unlike more recent works, the authors do not assume the reader to be familiar with the subject. For this reason, the book is a great resource for personnel attempting to gain knowledge about CM for the first time. A brief history of configuration management also provides insight into why configuration management is valuable and what could happen without it. Also of special interest are chapters two and four, which deal with the maintenance side of configuration management, include job descriptions of each configuration team member, and provide the conditions and steps necessary to correctly change the system.

6. Hajek, Victor G. *Management of Engineering Projects*. McGraw-Hill Book Company: New York. 1984.

   The majority of *Management of Engineering Projects* is focused on general engineering management rather than configuration management. Chapter 14, however, provides a useful, brief introduction to configuration management. The first part of the chapter presents the general principles of configuration management, which include explanations on each of the phases of configuration management in a product's life cycle. Towards the end of the chapter, the configuration management discussion focuses on managing software development.

Focused Resource List

These materials focus on specific aspects of configuration management. They are more specific and technical than the fundamental resources.

1. Dart, S. "Concepts in Configuration Management Systems", Third International Software Configuration Management Workshop*,* ACM Press, June 1991.

   URL: http://www.sei.cmu.edu/legacy/scm/abstracts/abscm_concepts.html
   This Web page provides a definition of configuration management, along with a statement of its primary purpose. The article focuses on the development of configuration management for large-scale software engineering products, but does not delve into software specific matters and therefore can be used as an introduction to configuration management in general. The article also has a comprehensive list of goals that configuration management should accomplish and provides guidance on how to attain them. Also included is a discussion of different configuration management implementations, which could provide a more thorough understanding of the capabilities of configuration management. A bibliography provides links to other software configuration management articles.

2. Dart, Susan & Nadine Bounds. "CM Plans: The Beginning to your CM Solution." Carnegie Mellon University, 1998.

   URL: http://www.sei.cmu.edu/legacy/scm/papers/CM_Plans/CMPlans.MasterToC.html
   This paper provides directions for implementing a configuration management plan. It contains a brief and general overview of configuration management, but focuses on the planning aspect. Included also are the results of 10 interviews conducted by the authors regarding managers' opinions about certain planning techniques. An outline provides a starting point for developing a configuration management plan, and a bibliography contains references to basic configuration management books.

3. "Configuration Management Information Center: Book Shelf"

   URL: http://www.pdmic.com/cmic/publications/books.shtml

   Although many of the books are out of print and extremely difficult to find, this Web sites is a great resource for agencies interested in compiling a configuration management library because it lists about 50 books on the subject. Also, all the books are listed as links to Amazon.com, which contains a more detailed description of some of the more popular books.

4. Harvey, Katherine E. "Summary of the SEI Workshop on Software Configuration Management" Carnegie Mellon University, December, 1986. URL: http://www.sei.cmu.edu/pub/documents/86.reports/pdf/86tr005.pdf

   This paper is a summary of the topics discussed at a 1986 meeting on software configuration management. Although the meeting focused on software configuration management, some principles can be applied to configuration management. A long discussion on a proposed system of configuration control boards includes the characteristics of an ideal CCB. The author's proposed system would be extremely useful for an industry that foresees the engineers/developers and the CCBs conflicting over design. The author also proposes a system to enforce documentation and to ensure the creation of baselines during the development process.

5. **Software Configuration Management - Software Engineering Institute**
   http://www.sei.cmu.edu/legacy/scm/scmHomePage.html

   The Software Engineering Institute (SEI) was established by the U.S. Department of Defense to focus on advancing the state of software engineering and has emerged as a leading worldwide authority on software engineering. This site serves as the portal to various papers, reports, and presentations developed by SEI on the topic of configuration management. The papers most applicable to configuration management in general have been detailed in this review. Many other papers contain information that pertains only to software configuration management (SCM), such as automated tools for SCM and forecasts for the future of SCM.

6. **Rigby, Ken. "Configuration Management Plan – Model Text" 1998.**
   http://www.airtime.co.uk/users/wysywig/cmp.htm

   This Web site provides a model text for a configuration management plan. It provides the necessary language to create a tailored configuration management plan and includes sections on configuration identification, control, status accounting, and audits. It also briefly explains the goal of each section of the configuration management plan and provides links to more specific, detailed reviews of the sections.

7. Tuffley, David. "How to Write Configuration Management Plans" Tuffley Computer Services Pty. Ltd. 2000.

   http://www.tuffley.aust.com/tcs20005.htm

   Although this site is basically an advertisement for the book *How to Write Configuration Management Plans*, it specifies the general goals of a configuration management system and provides a link to the book's table of contents. The table of contents can serve as an outline for a configuration management plan because it includes many of the necessary elements described in standard IEEE 1042-1987.

8. "TWRS Configuration Management Program"

   http://www.hanford.gov/twrs/cmpp/cmpphome.htm

   The Tank Waste Remediation System Configuration Management (TWRS) Web site contains two links to configuration management plans. The first can be found by clicking on the "product's life cycle" link. The second can be found by clicking on the "HNF-1900, Tank Waste Remediation System Configuration Management Plan" link. Although both plans contain essentially the same plan, HNF-1900, TWRS CM Plan is better worded and looks more like an official document. The first link, however, contains more information regarding the assignment of responsibilities and training of employees. The HNF-1900, TWRS CM Plan is a more specific document and includes detailed descriptions of how to implement the configuration management system in the TWRS environment. The first link leads to a CM plan, which provides explanation for all of its requirements and is, in general, easily readable.

9. "Configuration Management"

   http://www.oingo.com/topic/10/10251.html

   This Web site is a portal to many other configuration management Web sites, including some that are referenced in this paper.

10. "Software Engineering Standards – Configuration Management"

    http://www.12207.com/test.htm

    This Web site contains links to order the twenty most popular configuration management standards.

11. "Standards MIL-STD Configuration Management Software Bob Kolacki Experience"

    http://www.kolacki.com/critical_standards.htm

    This Web site lists many government standards, such as those written for the U.S. Department of Defense, the armed forces, and NASA. When one standard is clicked on, a list of complimentary standards is brought up. There are, however, no direct links to any standards.

12. "CM Resource Guide"

    http://www.cmiiug.com/sites.htm

    This Web site provides many links to other configuration management resources, including conferences, books, Web sites, training, professional organizations, and standards.

13. "Configuration Management – Quality Resources Online"

    http://www.quality.org/html/config.html

    This Web site provides a large number of links to a variety of Web sites and documents concerning configuration management, including links to lists of books and training courses. The Web site also includes links to documents providing detailed explanations of configuration management.

14. "NASA Software Configuration Management Guidebook"

    http://satc.gsfc.nasa.gov/GuideBooks/cmpub.html

    This guide provides a detailed description of a comprehensive software configuration management system. Included are sections covering configuration identification, control, status accounting, and authentication—all tailored to managing a software product.

15. "IEEE Standards Online Search"

http://standards.ieee.org/catalog/olis/search.html

This Web page allows users to search the IEEE Web site for a desired IEEE standard.

Transportation Specific Resources

This section contains resources specific to configuration management for transportation systems.

1. Gonzalez, Paul J. "A Guide to Configuration Management for Intelligent Transportation Systems," Mitretek Systems, Inc. April 2002.

   This document was prepared for the Intelligent Transportation Systems Joint Program Office of the USDOT. It includes four major chapters:

   - Introduction.
   - Configuration Management Principles.
   - Configuration Management and ITS Systems.
   - Configuration Management Tools.

   The paper describes all major principles involved within CM in the context of an ITS, which makes it a very valuable resource. The sections describing CM use during ITS system development and during system operation among the document's strongest points.

2. Smith, Brian L. "Configuration Management in Transportation Management Systems," Transportation Research Board. Washington, DC, January 2001.

   This document identifies how configuration management is currently being developed and used by transportation management systems. It is intended as a resource document for professionals just beginning to apply CM. Agency managers and administrators, as well as other technical personnel, in both the public and private sectors can use this report as a reference tool to locate more in-depth material to support CM programs. The document addresses the fundamental concepts and principles of CM, the need for CM within transportation management systems, and some CM resources. Also, it contains information about the status of CM within transportation departments as of the beginning of 2001 and detailed case studies of the use of CM both outside and within the transportation field. A glossary is included. An appendix contains an example CM tool.

3. Southwest Research Institute. "TRF Texas Configuration Management Strategy – Version 1.0," Texas Department of Transportation. October 2000.

   This document, prepared by the Traffic Operations Division of the Texas DOT, proposes a plan and strategy for its configuration management system. Although it is written for the TDOT, the focus of this document is on software configuration management. The document provides a detailed description of the Traffic Operation Division's proposal with descriptions of each facet of configuration management. Of particular interest is appendix B, which contains an easy-to-follow, configuration decision control flow diagram. The configuration management plan put forth is well thought out and easily understandable.

4. National Engineering Technology Corporation. "Configuration Management Plan Overview," Caltrans. August 1997.

This document was intended to provide Caltrans with a typical, nonspecific configuration management plan to be used as a starting point for its configuration management system. This is an extremely useful document because instead of focusing on only software engineering, the overview is directed at determining a configuration management scheme for a transportation system. The outstanding part of this document is the attention to detail in appendix A, which not only lists all of the configuration items in a transportation system, but details the documentation that must accompany them as well. This document could serve as a model for other states beginning the configuration management planning process.

5. Krueger, Michael E. & Randy Woolley. "Southern California's Priority Corridor: System of Systems Approach to Configuration Management."

The paper contains an outline for the configuration management plan for the Southern California Priority Corridor, a project of the California Department of Transportation. It is the actual implementation of section 1.2 in the "Configuration Management Plan Overview", listed previously. The plan is a useful configuration management resource for transportation systems because it describes the Priority Corridor's approach and outlines the implementation of its plan, including the organization and information flow of its configuration management system. The ultimate goal of the plan is to allow integration of all southern California's ITS systems. Also included is a discussion on the costs of configuration management, which is unique because the majority of literature does not report any rule of thumb for cost estimation.

Standards List

This section provides brief descriptions of two relevant standards.

1. Configuration Management Plan Standard (IEEE-828-1998)

   An excellent resource to support the development of configuration management plans is the IEEE Standard for Software Configuration Management Plans. The standard addresses all levels of expertise, the entire system life cycle, roles of outside organizations, and the relationships of software and hardware. It provides an extensive list of items for consideration in key component areas. The standard provides a list of possible interfaces and information that must be defined for each interface. It also provides a list of information that must be addressed for subcontracted and acquired software. It handles each component of the configuration management process thoroughly, and it provides a section-by-section, cross-reference to the general standards. This standard supersedes standard IEEE-828-1990, and it is the only software configuration management standard to be offered by IEEE since standard IEEE-1042-1987 was withdrawn. This standard is listed as IEEE-828-1998 and can be purchased online at http://standards.ieee.org/catalog/software2.html

2. National Consensus Standard for Configuration Management (EIA 649). Electronic Industries Alliance. August, 1998

   Standard 649 is a comprehensive guide for implementing and maintaining a configuration management system. Both the U.S. Department of Defense and the U.S. Internal Revenue Service have adopted the standard as the basis of their own configuration management systems. The standard's scope is to explain the major components of a configuration management system during a product's life cycle, including the components' purpose, benefits, and best practices. The outline for each component description follows a pattern, beginning with a general description of the phase, which is followed by a detailed description of each aspect of that phase. Also, the standard summarizes each point in its principles, which are listed in annex B. Written as a general information piece on configuration management, the standard emphasizes that different environments/industries should customize their system to meet specific needs. The standard was developed with the U.S. Department of Defense and is compatible with the ISO 9000 series of standards.

   Also, EIA 649 will replace MIL-STD-973. The standard is listed as EIA 649 and can be purchased online at the Web site: http://global.ihs.com. A more detailed review of this standard is included in this review.

Software Configuration Management Resources

These resources focus on software configuration management.

1. **"Configuration Management Bibliography"** http://www.sei.cmu.edu/legacy/scm/bib/cm_bib.html

   This Web page serves as an introduction to software configuration management. It contains links and references to many other resources, including books, conferences, other Web sites, standards, and papers.

2. "Summary of Available CM Related Documents"

   http://www.sei.cmu.edu/legacy/scm/scmDocSummary.html

   This Web page is a resource guide to software configuration management. Like the "Configuration Management Bibliography", this page contains numerous links to papers, journals, slide shows, and conferences. Unlike the bibliography, however, all these resources are available online.

3. "Spectrum of Functionality in Configuration Management Systems"

   http://www.sei.cmu.edu/legacy/scm/tech_rep/TR11_90/TOC_TR11_90.html

   This paper describes the purpose and main components of a software configuration management system. The chapter on issues for configuration management users focuses on topics such as when to implement a configuration management system, levels of configuration control, and configuration management system functionality. The chapter focusing on functionality in actual configuration management systems provides examples and explanations of current systems.

4. "Issues in Configuration Management Adoption"

   http://www.sei.cmu.edu/legacy/scm/slides/adoption/SlidesCMadoption_01.html

   This slide show, prepared by Susan Dart, provides an explanation of how and why a configuration management system can be hard to implement. It begins with a brief introduction of the components of a configuration management system, and subsequently focuses on adoption issues. It describes why different configuration management solutions are necessary for different working environments and provides a typical configuration management adoption process.

5. "CM Really Is Exciting!"

   http://www.sei.cmu.edu/legacy/scm/abstracts/abscm_is_exciting.html

   This slide show, prepared by Susan Dart in 1992, poses a number of typical questions regarding implementing a configuration management system. Although these questions are never answered in the slide show, they provide an excellent resource to begin thinking about how to implement a configuration management system. Software configuration management tools and their functionality are listed. Current accomplishments of configuration management systems are cited, and a list of functions that need to be included in future systems is provided.

6. "Software Configuration Management: Advances in Software Development Environments"

   http://www.sei.cmu.edu/legacy/scm/abstracts/absscm_in_sde.html

   This paper discusses the role of software configuration management in software development. It also discusses state-of-the-art, software configuration management practices, as well as current trends.

7. "Configuration Management Systems"

   ftp://ftp.sei.cmu.edu/pub/case-env/config_mgt/slides/cm_tutorial.pdf

   After a brief introduction to configuration management, a discussion of configuration management planning highlights the most important functions of a plan. A number of questions that a configuration management planner should ask in order to tailor a configuration management system to his or her specific environment are cited throughout the slide show. Also, a list of tools is provided, along with a description of their general functionality. The slide show author gives his opinion of where configuration management is headed, as well as the functionality that new tools will provide.

8. **"A Software Engineering Resource List for Software Configuration Management"**

   http://wwwsel.iit.nrc.ca/favs/CMfavs.html

   This site contains links to many software configuration management resources, such as associations, conferences, products, and other large indexes of software configuration management information. Notably, it contains a link to a library of papers and essays regarding issues in software configuration management.

9. "Software Configuration Management at NRC"

   http://wwwsel.iit.nrc.ca/projects/scm/

   This site provides background into a software configuration management research institute, the Canadian National Research Council. Initially, it provides background into their objectives and the focus of the research. It also provides links to several research papers written by some of their personnel and other SCM sites.

10. "The State of Automated Configuration Management"

    http://www.sei.cmu.edu/legacy/scm/abstracts/absatr_cm_state.html

    This site contains an abstract and full text version of a research paper that discusses the SEI software process maturity model. It analyzes and summarizes the state of configuration management automation. The author lists several tools that are valuable to software configuration management and concludes by describing the need for a set of commonly understood CM services.

11. "Concepts in Configuration Management Systems"

    http://www.sei.cmu.edu/legacy/scm/abstracts/absCMconcepts.html

    This site contains an abstract and full text version of a research paper that discusses the user functionality provided by existing configuration management systems. Because a lack of common terminology among SCM professionals is still lacking, each concept is discussed within the framework of its particular system. It lists a number of examples of relevant CM systems and briefly discusses their functionality.

APPENDIX C -
Summary of CM Plans

Summary of Texas DOT Strategy

Section 1 - Scope

This plan is designed for the Traffic Operations Division (TRF) of the Texas DOT, specifically for software configuration management applications. Major issues discussed include: configuration management organization, the methods by which issues are entered and processed, identification of documents, change request formats, and the baselining system.

Section 2 – Software Configuration Management

The section begins by describing the composition of a configuration control board and its typical duties. According to this plan, the CCB should be managed by an ITS branch manager, while other positions on the board may vary. CCB responsibilities include:

- Oversee the CM process.
- Develop and maintain CM procedures.
- Conduct oversight of the implementation of CM products.
- Monitor quality of CM products.
- Provide monthly status updates to the ITS branch manager, including:
  - Issues being tracked by issue tracking tool.
  - Configuration status reports on products under CM
  - A report of personnel hours used in previous month.
  - A report of anticipated personnel hours for coming month.

Section 2 lists the other internal and external organizations with which the TRF CCB should be involved. External organizations include:

- TDOT districts.
- Hardware vendors.
- Software consultants.
- Product validation team (may be internal)

This section specifies that other organizations that develop and maintain software applications for TRF are expected to follow the TRF CM procedures. Specific procedures that they are expected to follow are outlined in the scope of work documents for specific projects. Alternative CM procedures may be proposed and approved by the TRF CCB.

Section 3 – Software Configuration Management Activities

Section 3 describes how artifacts are identified and tracked, the process for implementing changes, and the process for performing configuration status accounting and auditing. The primary subsections are:

- Configuration identification.
- Product baselines.
- Configuration management plan.
- Backup and recovery plan.
- Change control.
- Configuration status reporting.

The configuration identification section discusses how documents and source code are identified and tracked. It specifies the specific information that should be attached to documents, including:

- A product ID.
- A document acronym.
- A version number.

The product team develops the proper IDs and acronyms, and the CCB manager ensures that the product identifier in the CM repository is unique. Section 3 lists the requirements for establishment of the version numbering system (Version *V.r*). A document's major version number, *V*, is incremented when significant new functionality is added. The minor version number, *r*, is incremented when bugs are addressed and smaller changes are made.

Typical software documentation should include:

- Software requirements specification.
- Software design document.
- Version description document.
- Software user's manual.
- Acceptance test plan.

The plan describes the two different repositories: developmental and production CM repositories. The developmental CM repository is the storage location for documentation and source code while the product is being developed. The production CM repository is where this information is stored once the product is ready for delivery. Once a system is placed in the production CM repository, it may only be modified after an Engineering Change Request (ECR) has been filed and approved by the CCB.

Information required on all ECRs is subsequently discussed. Twenty-two specific items are listed.

Baselines are the next items discussed in section 3. Once baselines are inputted into the developmental CM repository, the following information is to be recorded:

- How and when the baseline was created.
- Purpose of the baseline.
- A list of ECRs implemented for this baseline.
- Files that were changed.

The establishment of a configuration management plan is discussed next. The CCB uses the plan to provide guidance and outline the policies and procedures that users are expected to implement. The CM plan is submitted to the CCB for review, and the board either approves it or returns it with feedback. The CM repositories are set up only after the CM plan has been established.

Next, the backup and recovery strategy is discussed. A separate backup and recovery plan is needed for both developmental CM and production CM. During development and modification, the developmental CM must be backed up daily. The plan provides a list of media that can be used to backup this information, such as CD-ROMs and tape. The restoration process should be tested bimonthly on a computer that was not involved in the development process.

The production CM also should be backed up daily. Because production CM requires fewer changes than developmental CM, it is only necessary to record the changes and not the entire documents. The entire production CM repository should be backed up either monthly or quarterly, and the restoration process should be attempted on a computer that does not contain the production CM. The CCB is responsible for ensuring that adequate backup procedures take place.

The next major topic in Section 3 is change control. For TRF purposes, change control is initiated by identifying issues and entering them into an issue-tracking tool. The ITT is a Web-based system that automatically generates emails to the CCB manager when a new issue has been inputted into the system. The CCB addresses emergency issues as quickly as possible. Periodically, the CCB manager converts the issues to ECRs, at which point the CCB has the following options:

- Approve the ECR
- Deny the ECR
- Request clarification for the ECR
- Request internal research be performed on the ECR

The CCB meets monthly, either in person or via teleconference, to discuss ECRs,. For ECRs that have been denied or that have had more information about them requested, emails are automatically generated to the submitter, informing him or her of the status. Typically, technical staff is assigned to work on the ECRs requiring internal research. Similarly, approved ECRs are updated in the ITT and assigned to a staff member to begin work.

Section 3 also discusses the process for local source code change control. A staff member checks out the necessary files from the production CM repository and performs only the tasks specified by the ECR. Once the tasks have been completed, the staff member will perform tests and subsequently pass the modified files to the Product Validation Team. Through this process, the staff member is to create documentation for the modifications to be submitted to the Product Validation Team.

The next topic describes in section 3 is remote source code change control. Because many districts are involved in this system, local district staff sometimes will want to modify source code that TRF maintains. The same process is used as is used for other modifications, whereby the local staff submits ECRs to the CCB. If approved, the source code is placed in a staging area for alteration by local staff. The code is baselined, however, so that the new version is district specific and leaves the original source code unmodified. If the source code for the whole system is eventually changed, meaning that the baseline has been altered, local district staff is notified of any branched code to be affected.

Configuration status reporting is the last topic addressed in section 3. Configuration status reporting involves the tracking and reporting of the product artifacts under CM. On a monthly basis, reports are generated, which list:

- The version of the artifact.
- A revision history of the artifact.
- The current status of the artifact.

This information is gathered by performing CM audits. During the audit process the product artifacts are checked to ensure that the changes implemented were approved by the CCB and that the relevant standards were adhered to. The strategy lists the information expected to be included in the audit. The following is the process that is to be followed for audits:

- CCB assigns a staff member to execute the audit.
- Staff member creates the report.
- Staff member reviews the report and notes discrepancies.
- Staff member reviews the structure and facilities of the CM library system.
- Staff member verifies the completeness and correctness of the baseline library contents.
- Staff member finalizes the CM audit report.
- Staff member presents the report to the CCB.

Also included in this section is a discussion of the product release process audit, which is designed to ensure that the current product release is the one that is being distributed to customers. It then lists specific information to be included in these audits. This is the conclusion of the TxDOT TRF Configuration Management Strategy.

Southwest Research Institute. (2000). TRF CONFIGURATION MANAGEMENT STRATEGY (SwRI Project No. 10.04594-Document No. 72). San Antonio: Southwest Research Institute.

Summary of Georgia NaviGAtor CM Plan

This document summarizes the configuration management plan developed for the Georgia NaviGAtor system. The plan is divided into six areas:

- General CM information.
- Configuration management control procedures.
- Configuration control board.
- Software management procedures.
- Hardware management procedures.
- Design configuration management procedures.

Section 1 – General Overview

The configuration management plan is one of three control tools GDOT uses to manage the NaviGAtor system (the other two are the maintenance plan and the Technical Integration Working Group). GDOT uses the configuration management plan to manage the expansion of its NaviGAtor system, which includes adding fiber optic cable, communications hubs, field devices, and changes in hardware. The primary objective of the configuration management plan is change control throughout all stages of this expansion.

This section introduces the four major processes of the NaviGAtor configuration management system: identification, control, status accounting, and audit and review. The identification process includes identifying all system components, such as documents, drawings, software, and hardware, by name, identification number, and version. The control process maintains a stable configuration while changes are being implemented to the system and does so via the configuration control board (CCB). Status accounting involves the recording and reporting of change requests in order to maintain information on the potential impacts of a change. Finally, the audit and review process ensures that correct procedures are being followed and that the configuration management program is being used to maximum benefit.

Section 2 – General CM Information

This section describes the required resources for effective configuration management. First, a table (reproduced in table B-1) details key positions in the configuration management system and lists their responsibilities. The document states that the two major functions of the CM team are to serve as CCB members and to perform administrative duties, such as overseeing design reviews, monitoring schedules and budgets, and recommending new processes and procedures.

TABLE B-1: CM Team Responsibilities by Member	
Team Member	Responsibility
CM Manager	CCB Chairperson Plans and implements overall CM program Prepares and provides CM status reports Provides CM training Identifies CM resources Directs overall CM activities Maintains and develops CM procedures Plans and implements formal CM audits Identifies CM baseline requirements Attends formal project reviews
Program Manager	CCB permanent member Provides appropriate schedule, budget and resources Helps in planning overall CM program Oversees overall project reviews Identifies CM report requirements Helps CM manager determine CM training for GDOT employees Helps CM manager determine CM baseline requirements
CM Advisor	CCB advisor Recommends training requirements Recommends new CM procedures or changes to existing ones Helps CM manager monitor overall CM activities
Software Manager Hardware Manager Systems Integrator Operations Manager Design Manager	CCB permanent member Verifies that personnel are following CM procedures Assists in CM audits Evaluates and manages COTS software (if applicable) Provides Q/A evaluation and assurance of changes to baseline items Initiates and/or attends formal project reviews Help determine training requirements by providing expertise in each functional area
Documentation Manager	Attend CCB as administrative help to CM manager Maintains documentation repository Assists in CM audits Evaluates and manages COTS software (if applicable)

The next section describes baselines and their requirements, including items that are under baseline control such as documents, drawings, software, and hardware. Finally, the CCB is explained; the major action of the CCB is to review and either approve or reject change requests. Change requests are submitted using a System Change Request form and no change is permitted without CCB approval.

Section 3 – CM Control Procedures

Section 3 describes six specific procedures of the CM plan beginning with documentation/drawing management. As consistency and traceability are needed for effective configuration management, this area covers production and control procedures such as numbering conventions, formatting, and revision control. The next control procedure is data archive and release control, which manages documents, drawings, forms, and software data so that earlier versions of such items are available even after related change requests have been approved and implemented. Training is the third control procedure and is considered “the most important part of the overall CM plan.” Training is to be conducted by the CM advisor or manager, and classes are to include “real life problems and situations as they relate to the attendees’ jobs and CM principles.” The fourth procedure, status reporting, is the recording and reporting process for CM item information and includes change request reports, change request analysis reports, and audit reports. The fifth procedure is auditing, which establishes a plan for continual monitoring of CM processes and procedures. Specifically, the auditing process develops the required audits, their content, and timing, including audits of GDOT sections and even the CM manual itself. Finally, a COTS software control procedure controls the review, purchase, storage, and control of all COTS software used in the NaviGAtor system.

Section 4 – Configuration Control Board (CCB)

As stated by the CM manual, “it is the function of the CCB to review and approve or reject all requested changes for hardware, software, documentation and drawings that are under CM control.” The CCB is not to be a “preliminary investigation tool for problems,” but rather a decision-making entity evaluating recommended resolution to problems. Therefore it is essential that the mechanism for requesting a change, the System Change Request form, be thorough and complete, because, as the CM manual states, “the SCR process is only as good as the information provided.” The SCR is completed by the originator, a change assessment and resolution leader (assigned by the CM manager), and the CM manager. The SCR includes information such as:

- Name of originator, CAR leader, and CM manager.
- Type of change.
- Reason for change.
- Affects.
- Priority.
- Description of condition.
- Recommended solution.
- Approval.
- Updated data assignments.
- Tracking numbers.

- SCR history.

The CCB is to meet regularly to decide upon SCRs using the process illustrated in figure B-1.

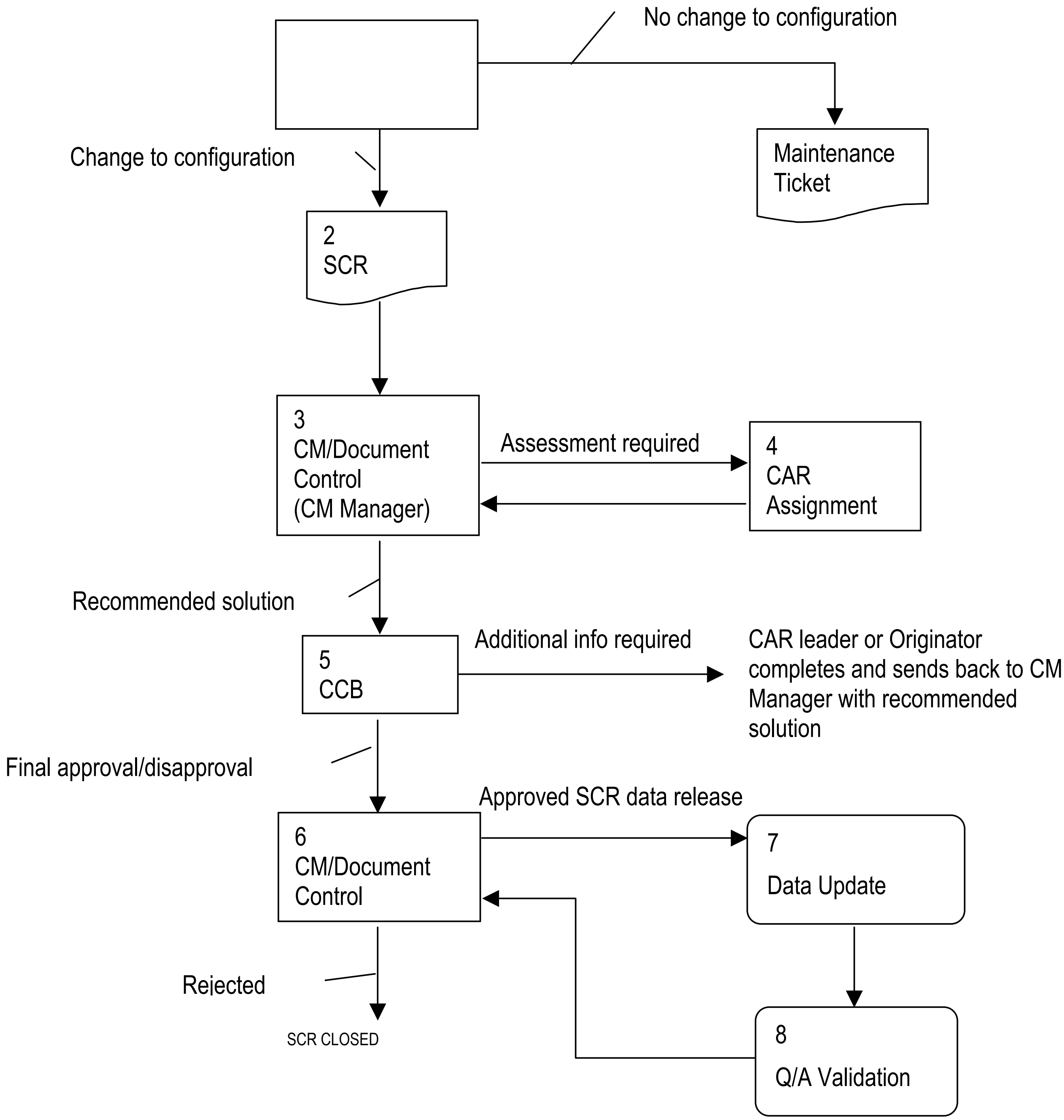


Figure B-1: SCR Flow

Section 5 – Software Management Procedures

This section specifies the CM processes to be used during the software development cycle. First, the required reports are described, including the system requirements specifications, high-level software design document, detailed software design document, system test procedures, system test report, and software change description document. Next, the methods of configuration identification are explained so that all baseline items are assigned consistent and unique names and numbers. Finally, the manual details the tools for software change control, which include the SCR (standard for any change within the NaviGAtor system) and ClearCase, a software management tool.

Section 6 – Hardware Management Procedures

This section of the CM manual is still a work in progress, but it may be safe to assume that it will include procedures for configuration identification, required reports, change control, status accounting and auditing.

Section 7 – Design CM Procedures

The majority of the Design CM Procedures section describes SCR submittal and timing, including a timeline of SCR activity compared to design activity. A summary of this timeline is provided in table B-2.

Table B-2: SCR Submittal Timeline

Design Activity	Days	SCR Activity	SCR Notes
Preliminary Design Review	1	Submit 1st SCR to CM manager if assessment is required (submit approximately 1 month later if assessment is not required)	Possible changes to existing drawings fiber allocation, special provisions and software.
	50	1st SCR submitted to CCB	
Start of Final Design Phase	60	1st SCR data updated	
Final Field Plan Review	150	Submit 2nd SCR to CM manager	Possible additional changes to drawings and special provisions resulting from final design phase.
	160	2nd SCR to CCB	
Contract Submittal	170	2nd SCR data updated	
	180	Submit 3rd SCR to CM manager	Possible additional changes to drawings and special provisions resulting from contract review.
	190	3rd SCR to CCB	
Advertisement	200	3rd SCR data updated	
	210	Submit 4th SCR to CM manager	Possible update to drawings and special provisions from contract advertisement.
	220	4th SCR to CCB	

Contract Letting	230	4th SCR data updated	advertisement.
End of Construction		Submit 5th SCR to CM manager	Possible update to drawings to incorporate “as-built” changes.
		5th SCR to CCB	
		5th SCR data updated	

APPENDIX D - System Descriptions

Appendix D provides the reader with a background on the systems used to illustrate CM concepts and practice throughout the guidance document.

Southern California Priority Corridor

The Southern California Intelligent Transportation Systems Priority Corridor is the site of a large integration effort involving multiple ITS systems. As one of four corridors identified by the 1991 Intermodal Surface Transportation Efficiency Act, the objective of the Corridor is to fully deploy and showcase ITS potential. The Corridor serves the counties of Los Angeles and Orange, and the major urbanized portions of Riverside, San Bernardino, San Diego, and Ventura counties. The program includes a number of smaller projects, currently at various stages. Some of the goals of the program include: increasing the safety of travel systems, aiding in the development of intelligent vehicle development, and enhancing the transfer of passengers and goods from place to place. The integration is providing both transportation management possibilities as well as increased traveler information services.

Georgia NaviGAtor

NaviGAtor is the intelligent transportation system for the Georgia Department of Transportation and combines video monitoring and detection with emergency response systems and public input. Based on information gathered through the various sensors, the system formulates a response plan and then communicates it to the public. One of the primary goals of NaviGAtor is to link the central traffic management center to transportation control centers in surrounding counties, the City of Atlanta and the Metropolitan Atlanta Rapid Transit Authority, thereby providing an enhanced ITS capability that serves more than 220 freeway miles. Some of the major features of the NaviGAtor program are: the Motor Vehicle Emergency Response Team, roadside accident investigation sites, traveler information kiosks and free cellular incident response service.

Maryland Coordinated Highways Action Response Team II (CHART II)

As a cooperative program between the Maryland Department of Transportation and the Maryland State Police, CHART, Maryland's Transportation Management System, aims to improve real-time operations of Maryland's highway system through its ITS component, CHART II. Specifically, CHART II is designed to monitor traffic conditions and issue advisories to motorists based on information gathered from speed detectors, loop detectors, cameras, weather sensors and cellular calls from the public. The system utilizes permanent and portable message signs to disseminate the information about traffic conditions to the public. CHART II has a central statewide operations center and local traffic operations centers. Data are stored at the nearest traffic operation center and are retrieved by the statewide operations center when needed. One of the goals of this configuration is to provide redundancy in case of failure of a single site.

Richmond, VA Smart Traffic Center

The Richmond Smart Traffic Center is one of three STCs in Virginia with the stated goals of:

- Local traffic and transportation operations and management in [the Richmond] district.
- Regional traffic incident and coordination within coverage area.
- Coordination with nearby STCs and/or transportation emergency operations centers for regional or statewide transportation operations and incident management.

The Richmond STC uses sources such as police, VDOT offices, and other emergency responders to provide highway incident information to the 4 cities and 14 counties in the Richmond district. Some of the hardware that the system employs includes: variable message signs (VMSs), highway advisory radio (HAR), portable message signs, and closed-circuit video cameras. The system operates 24 hours a day, 7 days a week.

APPENDIX E -
List of References

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Kimley-Horn and Associates, Inc. and Open Roads Consulting, Inc. (2001). *Richmond Smart Traffic Center: Software Configuration Management Plan*. Richmond: Virginia Department of Transportation.

Mitretek Systems, Inc. (2002). *A Guide to Configuration Management for Intelligent Transportation Systems.* Washington, D.C.: Federal Highway Administration.

TransCore, ITS, Inc. (2001). *Georgia Department of Transportation: NaviGAtor Configuration Management Manual*. Atlanta: Georgia Department of Transportation.

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APPENDIX F - List of Acronyms

CAR – Change Assessment and Resolution

CCB – Configuration Control Board

CHART – Coordinated Highways Action Response Team

CI – Configuration Identification

CM – Configuration Management

CMO – Configuration Management Office

CMS – Configuration Management Subcommittee

CMTT – Configuration Management Technical Team

COTS – Commercial-Off-the-Shelf

CSA – Configuration Status Accounting

DOT – Department of Transportation

ECP – Engineering Change Proposal

EIA – Electronic Industries Alliance

FCA – Functional Configuration Audit

FHWA – Federal Highway Administration

IMB – Issue Mediation Board

ITS – Intelligent Transportation Systems

PCA – Physical Configuration Audit

PRB – Problem Review Board

SCPC – Southern California Priority Corridor

SCR – System Change Request

SQL – Standard Query Language

STC – Smart Traffic Center

TMS – Transportation Management System